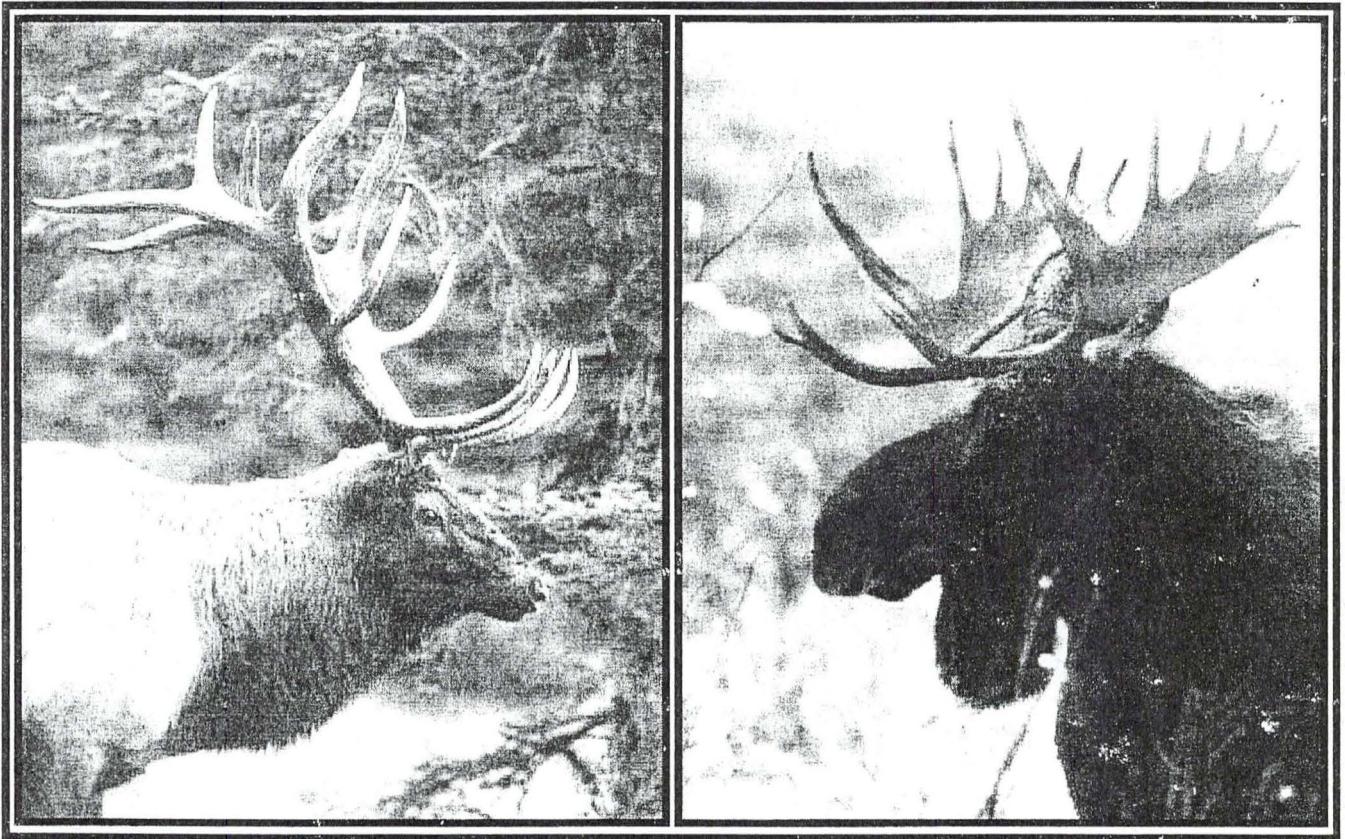


THESIS/
REPORT
BURCHAM, MILO

FINAL REPORT: STUDY OF SYMPATRIC MOOSE
AND ELK IN THE GARNET RANGE OF WESTERN
MONTANA, 1997-2000

Final Report:
Study of Sympatric Moose and Elk
In the Garnet Range
of Western Montana,
1997-2000

School of Forestry
University of Montana
Missoula
December 2000



Submitted by:

Milo Burcham

C. Les Marcum

Dave McCleerey

Mike Thompson

Agreement #: 00-JV-1222043-517

Final Report:
Study of Sympatric Moose and Elk
in the Garnet Range
of western Montana,
1997-2000

School of Forestry
University of Montana
Missoula
December 2000

Submitted by:

Milo Burcham
C.L. Marcum
Dave McCleerey
Mike Thompson

ACKNOWLEDGMENTS

Funding for this cooperative study was provided by:

Bureau of Land Management

Rocky Mountain Elk Foundation

Montana Department of Fish, Wildlife, and Parks

Boone and Crockett Wildlife Conservation Program

Five Valleys Chapter of Safari Club, International

U.S. Forest Service, Rocky Mountain Research Station

Plum Creek Timberlands, L.P.

University of Montana School of Forestry

Bill Stewart of North Star Aviation in Hamilton flew all telemetry flights during the study. Helicopter Wildlife Management of Salt Lake City, Utah and Helicopters by Oz of Marysvale, Utah, both captured moose for us. Veterinarian Dick Kinyon of Conrad, Montana and MDFWP helicopter pilot Lee Anderson captured moose for the pilot project. Ron Gipe of Flathead Helicopters helped conduct the moose survey. Rick Ward assisted with collection of vegetation data at moose locations during the summer 1999.

TABLE OF CONTENTS

Acknowledgments	i
Table of Contents.....	ii
List of Tables.....	iv
List of Figures.....	v
Abstract.....	1
Introduction.....	2
Study Area.....	4
Methods.....	9
Capture and monitoring.....	9
Vegetation plots.....	9
Data analysis.....	10
Moose survey.....	16
Results.....	19
Capture and monitoring.....	19
Vegetation plots.....	19
Moose habitat use.....	21
Moose use of disturbance classes.....	27
Spatial separation of moose and elk.....	29
Moose and elk habitat use.....	39
Use of security attributes by moose and elk.....	41
Population parameters.....	50
Observability.....	50
Moose survey.....	50
Calf production.....	52
Mortality.....	52
Home ranges.....	55
Blood and fecal analyses.....	55
Discussion.....	57
Capture and monitoring.....	57
Capture	57
Monitoring.....	58
Vegetation plots.....	58
Habitat selection by moose.....	59
Yearlong.....	60
Winter.....	61
Spring.....	62
Summer.....	63
Fall.....	63

Moose use of disturbance classes.....	64
Spatial separation of moose and elk.....	65
Habitat selection by moose and elk.....	66
Yearlong.....	66
Winter.....	68
Spring.....	69
Summer.....	69
Fall.....	70
Use of security attributes by moose and elk	70
Population parameters.....	72
Observability.....	72
Moose survey.....	73
Calf production.....	73
Mortality.....	75
Management Recommendations.....	76
Literature Cited.....	80

LIST OF TABLES

Table 1.	List of moose captured during study	20
Table 2.	Trees, by species and size class found at a sample of moose locations.	24
Table 3.	Variables in yearlong and seasonal RSF's for moose, in the order they entered the forward stepwise logistic regression model, for the moose study area.	26
Table 4.	Results of Bonferroni tests showing moose use of forest disturbance classes.	28
Table 5.	Variables in yearlong and seasonal RSF's for moose and elk, in the order they entered the forward stepwise logistic regression model, for the moose/elk study area.	40
Table 6.	Distribution and classification of moose observed from a helicopter on 5 - 6 January 2000, in the eastern Garnet Mountains.	53
Table 7.	Observed calf production for 1998 and 1999, and the dates that visuals were first obtained for the female and calf/calves.	54

LIST OF FIGURES

Figure 1	Map of study area showing location of Elk Creek and Chamberlain Creek burns.	5
Figure 2	Map of study area showing boundary of moose and elk home ranges and moose/elk study area.	14
Figure 3	Area covered by moose census, January 2000.	17
Figure 4	Percent of vegetation plots at moose locations containing browse species.	22
Figure 5	Level of browse use on browse species in vegetation plots at moose locations.	23
Figure 6	Use of forest disturbance history classes by moose #11.	30
Figure 7	Use of forest disturbance history classes by moose #12.	31
Figure 8	Use of forest disturbance history classes by moose #06.	32
Figure 9	Moose use of elk location density classes for January - February.	33
Figure 10	Moose use of elk location density classes for March - April.	34
Figure 11	Moose use of elk location density classes for May - June.	35
Figure 12	Moose use of elk location density classes for July - August.	36
Figure 13	Moose use of elk location density classes for September - October	37
Figure 14	Moose use of elk location density classes for November - December.	38
Figure 15	Use of distance-to-any-road categories by moose and elk during the non-hunting season, compared to the availability of each category.	42
Figure 16	Use of distance-to-any-road categories by moose and elk during the hunting season, compared to the availability of each category.	43
Figure 17	Use of distance-to-open-road categories by moose and elk during the non-hunting season, compared to the availability of each category.	45
Figure 18	Use of distance-to-open-road categories by moose and elk during the hunting season, compared to the availability of each category.	46
Figure 19	Moose and elk use of 4 categories representing the amount of coniferous forest within a 100 ha (250 acre) circle, surrounding moose and elk locations, compared to the availability of each category.	47

Figure 20	Moose and elk use of 4 categories representing the amount of coniferous forest within a 200 ha (494 acre) circle, surrounding moose and elk locations, compared to the availability of each category.	48
Figure 21	Moose and elk use of 4 categories representing the amount of coniferous forest within a 400 ha (988 acre) circle, surrounding moose and elk locations, compared to the availability of each category.	49
Figure 22	Monthly observability of moose from a fixed-wing aircraft during telemetry flights, compared to the mean estimated tree canopy cover and snow depth at moose locations.	51
Figure 23	100% minimum convex polygon home ranges for all female and male moose from the study.	56
Figure 24	Distance to mapped water of random points and moose and elk locations.	67

STUDY OF SYMPATRIC MOOSE AND ELK IN THE GARNET RANGE OF WESTERN MONTANA, 1997-2000

MILO G. BURCHAM, School of Forestry, University of Montana, Missoula 59812

C. LES MARCUM, School of Forestry, University of Montana, Missoula 59812

Abstract: Elk (*Cervus elaphus*) have been a major consideration in forest management in the western United States. Other ungulate species that are sympatric with elk, such as Shiras moose (*Alces alces shirasi*), have often received less management consideration. We studied a moose population in the Garnet Mountains of west-central Montana from 1997 to 2000, to learn more about moose habitat preferences. At the same time, we capitalized on elk data collected in a portion of the moose study area from 1993-1996, so that moose and elk habitat use could be compared. Logistic regression was used to model moose and elk habitat selection. We also used Bonferonni confidence interval tests to look at how moose used forest disturbance classes, and how moose and elk responded to roads and varying amounts of forest cover. Moose were found nearer riparian areas, and elk were found further from riparian areas, than expected. Some moose showed strong selection for clearcuts and burns that were greater than 15 years old. Moose showed seasonal avoidance of roads while elk avoided roads yearlong. Large blocks of forest cover, a feature considered desirable for elk security during the hunting season, received substantial use by moose, but were used less than expected by moose as the size of these areas increased. Survey results, seasonal observability, calf production, and mortality of radio-collared moose are also reported.

INTRODUCTION

Shiras moose (*Alces alces shirasi*) are the southern most occurring and smallest of the moose subspecies in North America. In the northern parts of their range, moose are of major importance to subsistence hunting (Reeves and McCabe 1997), recreational hunting (Reeves and McCabe 1997, Crichton 1997) and predator/prey relationships (Ballard and Van Ballenberghe 1997). Consequently, they are a significant factor in land management planning in many areas. In the southern portions of moose range, they occur at lower densities and share the landscape with many other, more abundant ungulate species, including elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*O. hemionus*). Also, because moose occur at lower densities than these sympatric ungulates, and occur near large human populations, strict harvest regulations ranging from no moose hunting to lottery-style drawings for very limited moose permits are the rule. As a result of many of these factors, Shiras moose in Montana have not received as much public attention, and as a result, management consideration, as have elk.

Elk have become a major consideration in forest management in the northern Rocky Mountains. Cutting unit sizes have been designed to maximize elk use while optimum cover/forage ratios were determined to maximize landscape productivity for elk (Leckenby 1984, Thomas et al. 1988). Road closures were designed to maximize elk use of habitat (Lyon 1979). More recently, as bull:cow ratios have declined, habitat management has included leaving large blocks of timber for security cover, and road closures to regulate hunter access (Marcum 1975, Perry and Overly 1976, Irwin and Peek 1983, Lyon et al. 1985, Canfield 1988, Lyon and Canfield 1991). While these considerations have benefitted elk, their impact on other wildlife, even other ungulate species such as moose, are not well known.

Comparatively little was known about the moose population in the Garnet Mountains. Aerial surveys in the 1970's and 1980's, identified concentrations of moose in and near the regenerating Elk Creek burn of 1961. Land management objectives and a hunting season were developed around this population of moose, however, this burn had become largely forested by the 1990's. No moose were observed in the Elk Creek burn during a systematic helicopter survey in December 1995, but 20 moose were observed in old clearcuts and forest openings in nearby areas. Despite several attempts to count moose between 1975 and 1995, results were variable giving scant information about the size, productivity, or even trends of this moose population.

While collecting data to further evaluate the effects of timber harvest on elk from 1993-1996, we realized the opportunity existed to measure how plans to manage habitat for elk, may influence a sympatric moose population. In addition to gathering basic habitat use and population data on moose, we were able to compare elk and moose data sets from the same area, and evaluate how moose and elk utilize the same landscape, and how moose utilize habitat attributes thought to benefit elk.

Our objectives for this project were to 1) determine moose habitat preferences in the relatively dry coniferous forests of the Garnet Mountains, 2) determine how moose are using the advancing seral stages of the Elk Creek burn, and if cutting units in the surrounding area are serving as replacement habitat, and 3) evaluate how management strategies for elk, particularly providing security habitat, influence moose habitat use.

STUDY AREA

The study area was in the eastern Garnet Mountains, which range from 9 to 60 km east of Missoula, Montana (Figure 1). Moose radio-collared for the study are concentrated in the eastern half of the mountain range, bordered, roughly, by Interstate 90 to the south, the Helmville Valley to the east, and the Blackfoot River to the north. Elevations range from 1,100 m along the Blackfoot and Clark Fork Rivers to 2,156 m on Elevation Mountain, the highest point in the Garnets. Topography varies from gently sloping ridges with steep to moderate slopes at higher elevations to the relatively flat flood plain of the Blackfoot River. Most drainages within the mountains are narrow without much flood plain development. Heads of larger drainages, generally, have gently sloping basins. The area has relatively few precipitous cliff or canyon areas, and no terrain above treeline.

Weather in the study area is typified by cool moist winters and hot, dry summers. Weather data collected at Lubrecht Experimental Forest (elevation 1,250 m) show an average minimum temperature of -13.2°C occurs in January, while the average maximum temperature of 28.2°C occurs in July. Annual precipitation varies from 30-74 cm, more than 2/3 of which falls in the winter and spring.

Approximately 80% of the area is forested. The forest overstory is predominately lodgepole pine (*Pinus contorta*) above 1,700 m on south aspects and above 1,550 m on north aspects. Mature to old subalpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea englemannii*), western larch (*Larix occidentalis*), and Douglas-fir (*Pseudotsuga menziesii*) are also found, predominately on north and east aspects. Subalpine fir and Englemann spruce may occur down to 1,340 m in mesic sites or stream bottoms. Douglas-fir dominates in nearly pure stands on dry

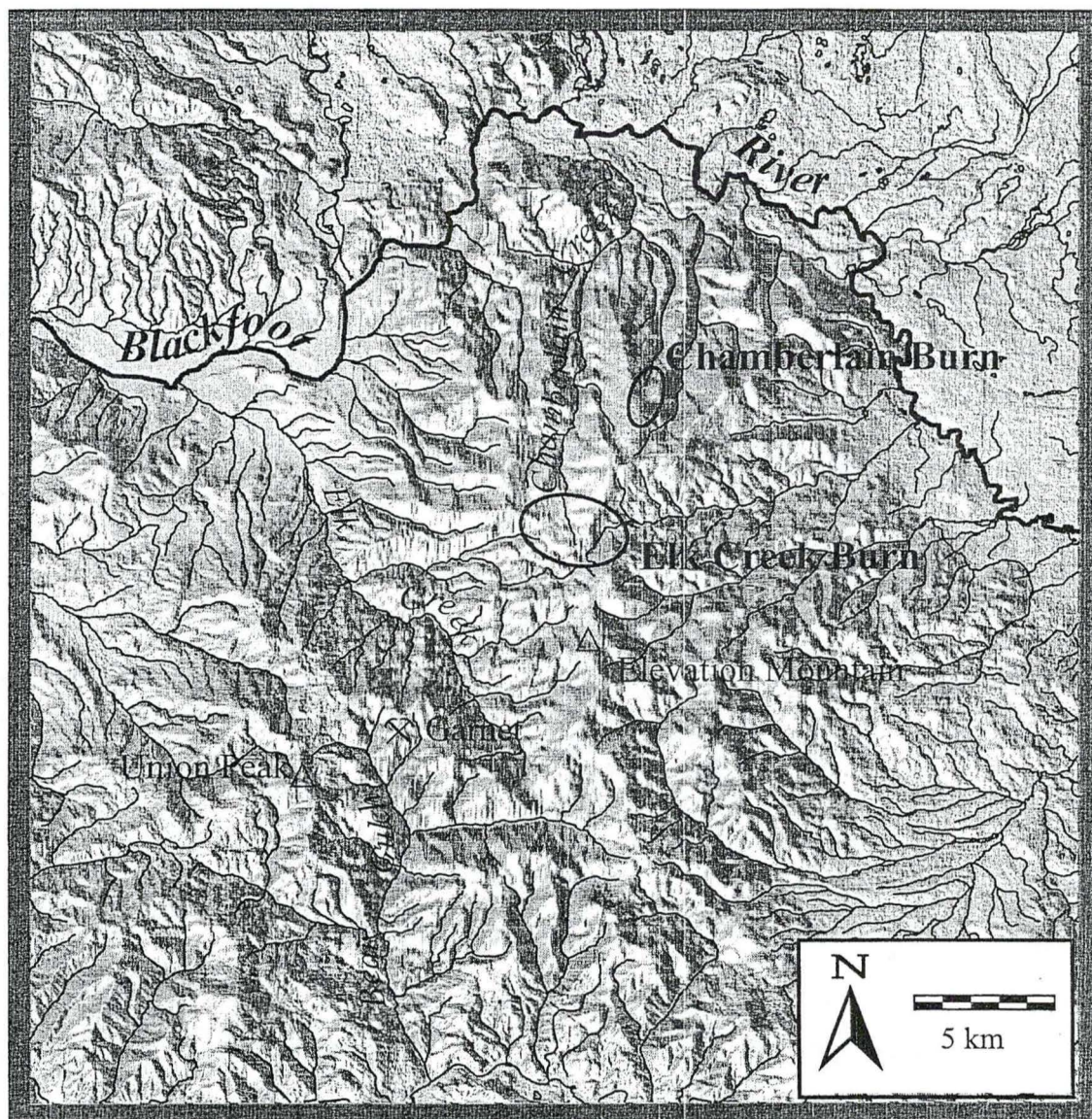


Figure 1. Map of study area showing the general locations of the Elk Creek burn (1961) and Chamberlain Creek burn (1994).

west and south aspects below 1,700 m, while on north and east aspects, or locally moist sites, Douglas-fir occurs in mixed stands with western larch. Ponderosa pine (*Pinus ponderosa*) commonly occurs with Douglas-fir on low-elevation dry sites.

Non-forested plant communities occur throughout the study area. Dry lower sites, such as open ridge tops and lower elevation slopes contain primarily bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*) and arrowleaf balsam root (*Balsamorhiza sagittata*). Forbs become more abundant at higher moist sites, and arrowleaf balsamroot and giant hyssop (*Agastache urticifolia*) are common. Hay meadows and pastures are planted with Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*), or alfalfa (*Medicago sativa*).

Shrub communities exist along streams, but are narrow in width, and often under forest canopy. Willow (*Salix scouleriana*) and red osier dogwood (*Cornus stolonifera*) are most prevalent. Alder (*Alnus sinuata*) may also dominate some riparian sites, while black hawthorn (*Crataegus douglasii*) and mountain ash (*Sorbus scopulina*), occur at low densities. Trees associated with riparian areas include Englemann spruce, subalpine fir, aspen (*Populus tremuloides*), and cottonwood (*Populus tricocarpa*). Aspen is a relatively rare type and does not occur in large stands, while cottonwood is more widespread, but associated with the larger streams and along the Blackfoot and Clark Fork Rivers. All of these riparian-associated species may also occur in clearcuts and burns throughout the study area, particularly at higher elevations and on cooler aspects.

Two forest fires influenced moose distributions in this study area, and are mentioned throughout this report (Figure 1). The Elk Creek burn occurred in 1961 and burned

approximately 417 ha. It has since regenerated to a dense, young lodgepole pine stand with a residual shrub component in the understory and along riparian zones. This burn created good moose habitat and was thought to have been responsible for an increasing moose population in the Garnets during the 1970's. The Chamberlain Creek fire burned approximately 494 ha in 1994 and remains in an early seral stage.

Biota of the study area were typical for vegetation types in the northern Rocky Mountains. In addition to moose and elk, mule deer and white-tailed deer were common. Black bears (*Ursus americanus*), and coyotes (*Canis latrans*) were present and undoubtedly preyed on young of all ungulate species. Mountain lions (*Felis concolor*) were also present and preyed on young and adults of ungulate species. Wolves (*Canis lupus*), although recovering in western Montana, were not known to be established in the study area during the study.

The study area is managed by the Bureau of Land Management (BLM), Plum Creek Timberlands, L.P., University of Montana's Lubrecht Experimental Forest, and Montana department of State Lands. Logging and timber production has been, and continues to be, the predominant use of the study area. Clear cuts and seed tree cuts were the most common form of harvest at higher elevation lodgepole pine, spruce-fir, and Douglas fir cover types. At lower elevations and on drier sites, select harvests of varying intensities were most common.

Mining has played a major role in the history of the Garnet Mountains, as evidenced by the Garnet Ghost Town, and extensive placer and ore mining remnants. Gold was discovered in the Garnets about 1865 in placer deposits near Bearmouth (Hammond 1983). Heavy placer mining activity, which has undoubtedly shaped present day riparian plant communities, took place in Deep, Elk, Tenmile, Felan, Day, Oliver, Jonathan, Harris, McMannus, McGinnis,

Cayuse, Melhorn, Cave, Williams, Bivens, Chicken Run, and First Chance creeks. Lode deposits were later discovered at Top O' Deep, Garnet, Copper Cliff, Coloma and other places. Over 5,000 people lived in the area by 1867 and at its peak over 1,000 lived in Garnet. The town was reduced to only 200 residents in 1905, and by 1920 it was essentially a ghost town (Hammond 1983). A few small mining operations continue to this day. Little mining activity took place in the Chamberlain Creek area where the moose and elk study areas overlapped.

Hunting was the primary recreational use of these lands. Elk and deer hunting was open to Montana residents by purchasing an "over-the counter" licence. The general season for male elk and deer ran 5 weeks, ending the Sunday following Thanksgiving. A fixed number of special permits for female elk and deer were distributed through a drawing. An archery season for either sex elk and deer ran 5 weeks, starting on the first Saturday in September. Moose were hunted by special permits for bulls only. Six permits were issued per season with 201 people applying for those permits in 1999. Black bears and mountain lions were also hunted.

Portions of the study area were managed for walk-in hunting. Much of the area where the moose and elk locations overlapped fell within the Blackfoot Special Management Area. This cooperative agreement between landowners and Montana Department of Fish, Wildlife, and Parks restricts vehicle access to 16,565 ha to provide security for elk and a quality experience for hunters.

METHODS

Capture and monitoring - Moose were captured using a Hughes 500 helicopter and net gun. Animals were located and captured during December or January. Moose were restrained with hobbles and fitted with collars made of fire hose containing 150-154 MHz transmitters. From each moose we made body measurements (head, hock, and total body lengths; chest and neck circumferences) and collected blood and fecal samples. Samples were sent to Montana Department of Fish, Wildlife, and Parks Lab in Bozeman to test for pregnancy, disease, and parasites. Aerial telemetry locations were obtained bi-weekly from a Citabria airplane fitted with a belly mount antenna. Locations were marked on aerial photographs of the study area and later transferred to USGS 7.5 minute topographic maps. UTM coordinates were then recorded to the nearest 10 m. Elk were captured both with net guns and Clover traps (Clover 1954, Thompson et al. 1989) and similarly handled and radio-collared. Telemetry for elk locations took place between 1993 and 1996 at weekly intervals from May through November.

Vegetation plots - We visited as many moose locations as time permitted during summer 1999 to measure vegetation parameters. Within a 0.04 ha (1/10 acre) plot centered on moose locations, as verified by moose sign such as tracks, tree rubs, and droppings, we recorded: slope position (drainage bottom, lower slope, mid-slope, upper slope, ridge top, drainage head), aspect, slope, distance to water, and forest cover type. Minimum, maximum, and mean sight distances, forest canopy cover, and tall shrub species canopy cover were estimated. We counted tree species within 6 size classes (seedlings and saplings < 1.2 m (4 ft) in height, 0-2.54 cm (0-1.0 in), 2.54 - 5.08 cm (1.0-2.0 in), 5.08 - 15.24 cm (2.0-6.0 in), 15.24 - 30.48 cm (6.0-12.0 in), and > 30.4 cm (12.0 in)), and counted shrub species within 3 size classes (0-61.0 cm (0-2.0 ft), 61.0 -

182.9 cm (2.0-6.0 ft), and > 182.9 cm (6.0 ft)). Level of browsing on shrubs (on a scale of 0-3, 0 being no use and 3 being heavy use), past forest disturbance, and the number of ungulate pellet groups were recorded.

Data analysis - A geographic information system (GIS) formed the basis of our data analyses. ARC/INFO (ESRI 1994) was used to characterize moose locations, elk locations, random points in relation to vegetation, hydrography, elevation, and roads. The Wildlife Spatial Analysis Lab at the University of Montana produced a vegetation map using Landsat Thematic Mapper (TM) digital coverages to classify vegetation within the study area. Cover types were mapped using a manual classification of urban, agriculture, and water and a training data classification of 11 other cover types:

- | | |
|------------------|---------------------------------------|
| -Urban | -Douglas fir/Lodgepole pine |
| -Dry-agriculture | -Western larch/Lodgepole pine |
| -Wet-agriculture | -Douglas fir/Ponderosa pine |
| -Grassland | -Mixed Englemann spruce/Subalpine fir |
| -Mesic shrubs | -Aspen |
| -Sagebrush | -Water |
| -Lodgepole pine | -Rock |
| -Douglas Fir | |

A total of 1,135 ground plots were used in the training data classification providing a final correct classification accuracy of 62.38%. The weighted resampling method Euclidian distance classifier, with a nearest member group spatial adjustment, was used for cover type classification. The canopy cover classification was based on histogram splits of MNDVI values

for the grassland, mesic shrub, sagebrush, and forest cover types. When cover type data were combined with canopy cover, 38 classes were created. These 38 classes were eventually combined to form the 7 vegetation types used in the analyses:

V1 - Non-forest (wet and dry agriculture, grassland, sagebrush)

V2 - Mesic shrub

V3 - Dry coniferous forest (Douglas fir, Douglas fir/lodgepole pine, western larch/lodgepole pine, Douglas fir/ponderosa pine)

V4 - Wet coniferous forest (mixed Englemann spruce/subalpine fir)

V5 - Aspen

V6 - Water

V7 - Rock

We developed a road theme using U.S. Geological Survey 7.5-minute topographic maps and aerial orthophotography (1:24,000 scale). This theme was manually edited to include new roads, correct errors, and update road status information. Three road variables were created reflecting vehicle access: distance to nearest road of any type (open or closed to motorized vehicles), distance to nearest road that was open to motorized vehicles yearlong or seasonally (closed for a portion of the year, typically during hunting season), and distance to nearest road open to motorized vehicles in winter (including designated snowmobile routes).

The hydrography layer used in our analyses was obtained from USGS 7.5 minute (1:24,000) topographic maps. A USGS digital elevation model provided elevation, slope, and aspect variables. Aspects were converted to a variable called “northeastness” (NE_NESS), an integer from 0-180, which reflected deviance from northeast, the coolest, wettest aspect (0

representing 45° or northeast, while 180 represents 225° or southwest).

In order to evaluate how moose responded to forest disturbance, we gave each polygon on the map a code referring to its disturbance history. Using detailed aerial photographs and personal knowledge of the area, we first coded all stands that had not been burned or logged in a way that noticeably changed forest canopy coverage. All disturbed stands were coded as either old cut, new cut, select cut, old burn, or new burn. Definitions were as follows:

CC1 - old cuts - clear cuts or seed tree cuts with advanced sapling regeneration, generally older than 15 years

CC2 - new cuts - clear cuts or seed tree cuts without advanced sapling regeneration, generally younger than 15 years

CC3 - timber harvests that noticeably reduced tree canopy cover, but left at least 30% tree canopy cover.

CC4 - the Chamberlain Creek burn (1994)

CC5 - the Elk Creek burn (1961)

CC6 - not disturbed, non-forest

CC7 - not disturbed, forest

The study area for moose was delineated by combining the 100% minimum convex polygons of all moose in the study area buffered by 150 m to account for telemetry error. The union of these polygons became the moose study area boundary. Within this area, we generated a set of random points equal to the number of telemetry locations used in these analyses. A 150 m radius circle around each location was used to account for telemetry error of moose and elk locations for vegetation analyses. Proportions of vegetation types (V1-V7) within the 150 m

radius circles were used in analyses. The point locations were used to describe elevation (ELEV), slope (SLOPE), northeastness (NE_NESS), distance to any road (DIST_RD), distance to year-round open road (DIST_R3), and distance to water (DIST_HY). Vegetation variables and physical habitat variables were tested for covariance. Variables with correlations greater than 0.65 were removed from models. We used logistic regression (SPSS 1999) to build seasonal resource selection functions (RSF's) and identify which variables best predicted yearlong, winter (1 December - 30 April), spring (1 May - 15 June), summer (15 June - 15 September), rut (15 September - hunting season) and hunting season (5 weeks, ending the Sunday after Thanksgiving) resource selection by moose (Manley et al. 1993).

To evaluate use of forest disturbance categories by moose, we intersected each moose home range with the forest disturbance coverage in ARC/INFO to determine the availability of each disturbance category to individual moose. If predicted use of a type was 1 or less observations, that type was removed from the analysis. The proportion of moose locations within each of the disturbance categories was then compared to the availability of each type and differences were tested using Bonferonni confidence intervals (Neu et al. 1974, Byers et al. 1984). To determine significance of simultaneous categories, we used a P value of 0.10.

The northern portion of the moose study area overlapped home ranges of 3 elk herds identified during our previous research from 1995-1997 (Burcham et al. 1998). This area of overlap provided an opportunity to evaluate moose and elk spatial distributions and habitat use in the same area (Figure 2). Home ranges of elk and moose were intersected to define a common area. Within this moose/elk study area, we first examined the spatial relationship of the 2 species. We used elk locations from the earlier study and created an elk density map using the

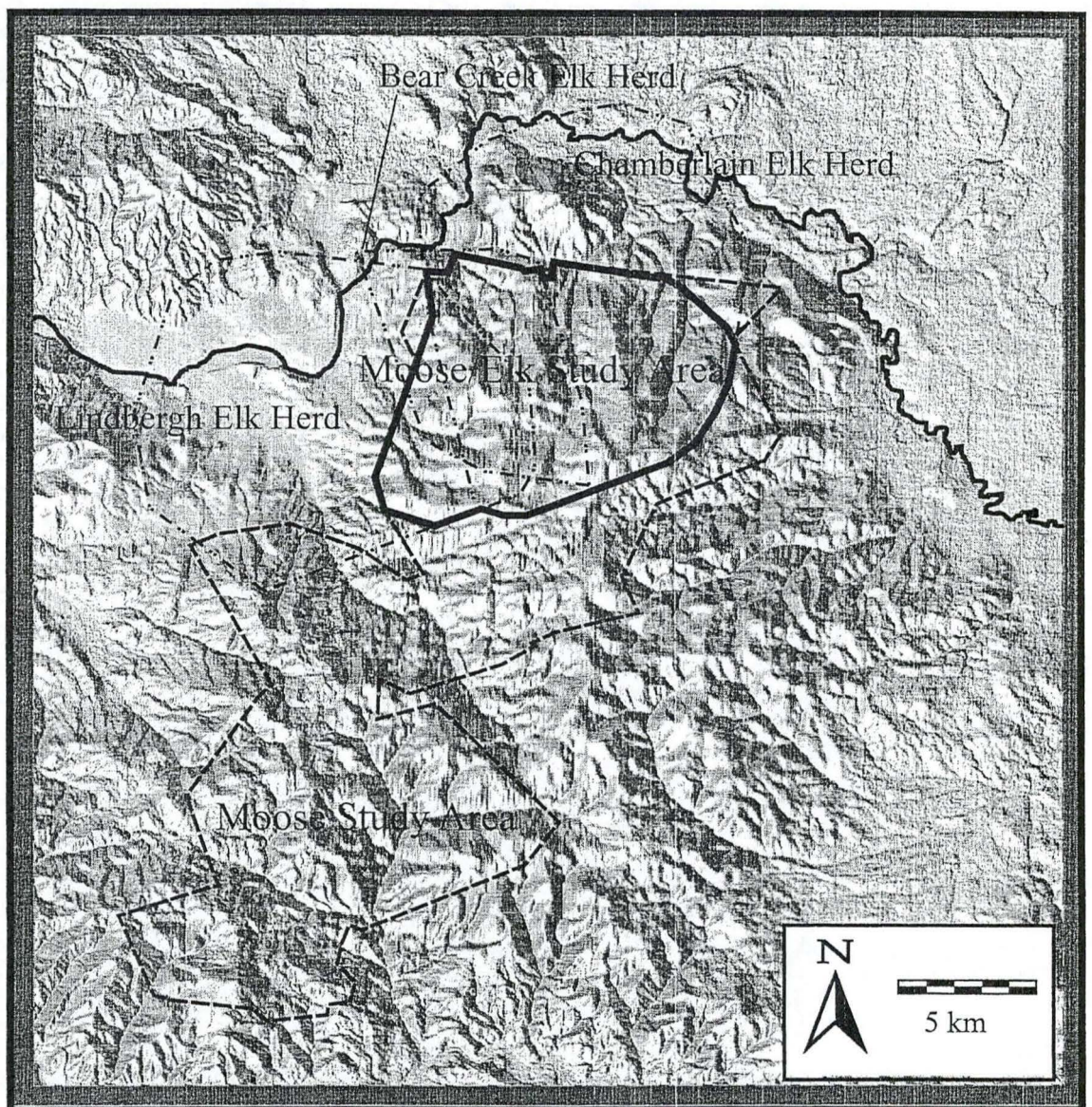


Figure 2. Map of study area showing the boundaries of 3 elk herd home ranges, the cumulative home ranges of all moose (moose study area), and the area of overlap (moose/elk study area).

POINTDENSITY command in ARC/INFO (ESRI 1994). We chose a 250 m radius circle in the POINTDENSITY command. The choice of circle radius is relatively robust and has little effect on resulting densities; because, as the area of the circle increases, so does the number of points that fall within the circle (ESRI 1994). Because of differences in both the numbers of radio marked elk and the number of radio locations for each of the 3 elk herds, densities for each herd were weighted by the number of radio locations per herd for the final point density map. This produced a map of year-long elk location densities. Moose locations for 6 bi-monthly periods (January-February, March-April, May-June, ...etc.) were then placed on this elk density map, and counts of the moose locations within elk point density categories were compared to the availability of each elk point density category using Bonferonni confidence intervals (Neu et al. 1974, Byers et al. 1984). We used a P value of 0.10 to determine significance of simultaneous categories.

As in the modeling of moose habitat use within the moose study area, we modeled both moose and elk habitat use within the moose/elk study area, where each species had the same habitat array available. Within this area, we generated a set of random points equal to the number of telemetry locations for moose used in these analyses. A 150 m radius circle around each location was used to account for telemetry error of moose and elk locations for vegetation analyses. The point location was used to describe elevation, aspect, and distance to roads and water. Vegetation variables and physical habitat variables were tested for covariance. Variables with correlations greater than 0.65 were removed from models. We used logistic regression (SPSS 1999) to determine seasonal resource selection of moose and elk.

Additionally, within this area of overlap, we examined how both moose and elk

responded to specific variables, that are considered to provide security habitat for elk during the hunting season (Marcum 1975, Perry and Overly 1976, Lyon 1979, Irwin and Peek 1983, Lyon et al. 1985, Hillis et al. 1991, Lyon and Canfield 1991, Canfield 1988). Distance to any road, distance to nearest road open to motorized vehicles, and percent of forest cover ($> 39\%$ canopy cover) within 100 ha (250 acre), 200 ha (494 acre), and 400 ha (988 acre) circles centered on moose and elk locations were tested.

Moose survey - Previous efforts to count moose in the Garnet Mountains produced variable results. From 0 to 20 moose were seen on 7 aerial counts between 1978 and 1996. However, without a marked sample in the population, there was no way to estimate the proportion of the population counted. Results have been variable, reducing the value of these counts, even for evaluating gross population trends.

We conducted a Lincoln-Peterson population index (Lincoln 1930, Oosenbrug and Ferguson 1992) using a modified Gasaway survey technique (Gasaway et al. 1986). On the 5th and 6th of January 2000, we hired a Bell 206 helicopter and pilot to conduct a moose census within the area used by radio-collared moose (Figure 3). This area was delineated into sub-units, and did not cover the entire Garnet Mountains. We flew these delineated sub-units in a contour pattern at low altitude to achieve complete coverage of as much area as possible. We stopped searching for moose within a subunit when snow depths became excessive and no recent moose sign could be observed. We increased search efforts in areas where fresh tracks were observed. Cost constraints reduced time spent searching large areas of dense forest canopy, where helicopter survey speed (and, in turn, total survey area) would have to be reduced.

Two observers and the pilot searched for moose. Once seen, we determined sex of

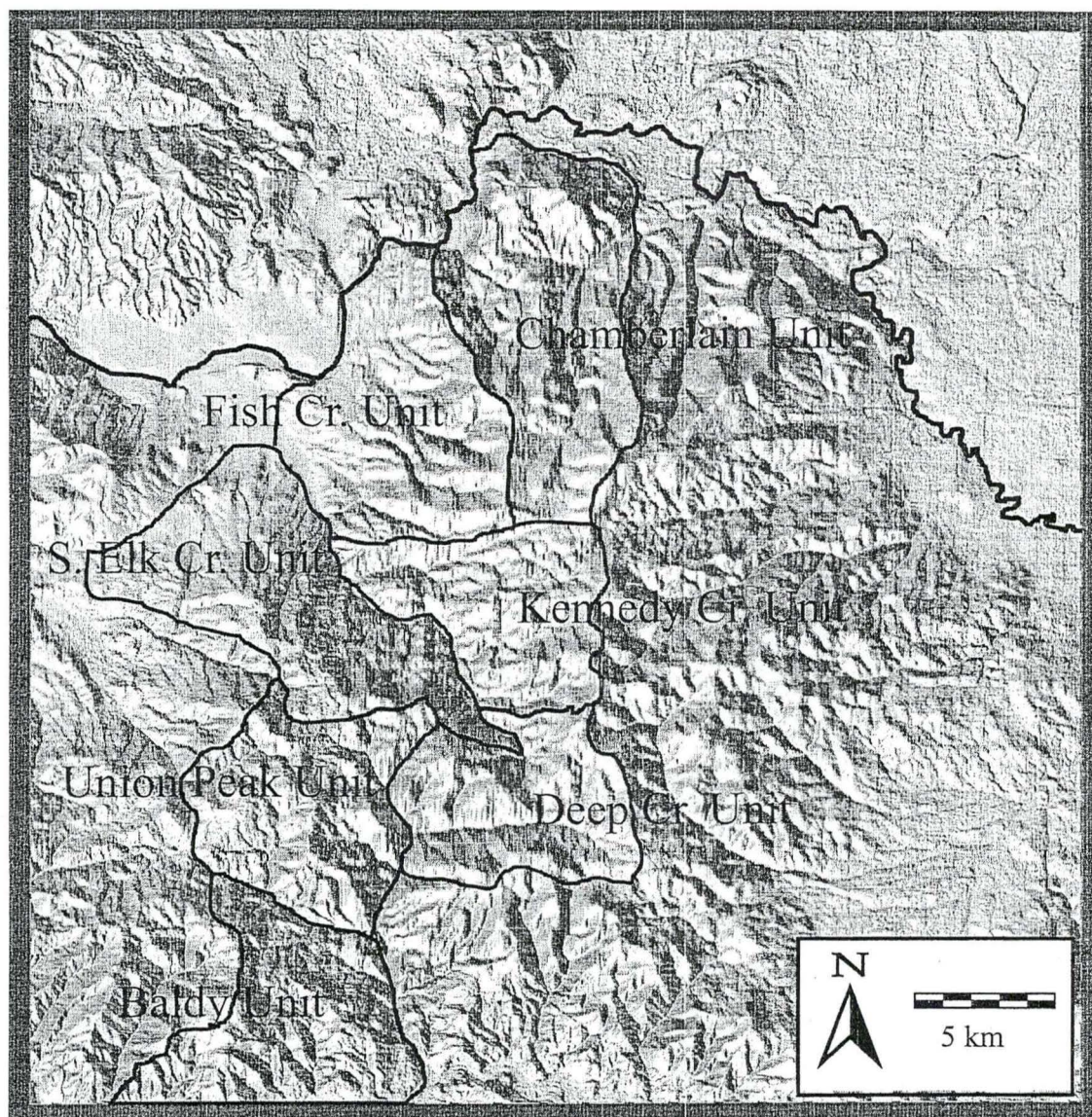


Figure 3. Area covered by moose census, showing individual count units, conducted 5-6 January 2000.

animals without antlers by looking for the white vulval patch of females. We recorded location, time, number of animals, age class, presence of a radio collar, activity, and conifer canopy cover.

RESULTS

Capture and monitoring

Capture - As a pilot study to this moose project, 2 moose were captured in December 1996 using a tranquilizer dart and carfentanil from a Hughes helicopter. Early, deep snow made finding moose difficult and only 2 moose were captured. One died 1 day later, approximately 1 km from the release site. The other, a young bull, was harvested by a hunter the following fall.

The moose study began one year later with the capture by net-gun of 12 moose in 3 days (16, 18, 19 December 1997) from a Hughes 500D helicopter. Seven females and 5 males were captured and released in good condition (Table 1). Seven additional moose (4 males and 3 females) were captured for the final year of the study on 19 February of 1999. These moose were also captured with a Hughes helicopter and net gun and released in good condition. Animals captured with net guns were restrained with hobbles, blind-folded, radio-collared, ear tagged, and measured before release. No injuries due to capture were noted other than minor cuts. Although female moose were preferred for this study, we captured moose opportunistically to attain a viable sample.

Monitoring - We obtained 769 telemetry locations of 19 radio-collared moose over 2 years (Table 1). Locations were acquired approximately 2 times per month. Two moose were followed for only a very short time: female #9 was found dead in spring 1998 after obtaining only 9 locations, and male #20 apparently slipped his collar before antler regrowth in the spring of 1999, after only 4 locations.

Vegetation Plots

During summer 1999, vegetation plots at as many moose locations as possible were

Table 1. List of moose captured during study, including moose ID# (Moose#), radio frequency (freq), frequency of back-up transmitter (altfreq), sex, estimated age at capture (age_est), cementum age, back-dated to capture date (age_cem), ear tag number (ear1), ear tag number (ear2), and radio-collar identification number (collar#).

Moose#	freq	alt freq	sex	age	est	age_cem	ear1	ear2	collar#
01	151.262	-	M	2			-	-	35568
02	151.713	-	F	3			35566	35567	35570
03	152.859	-	F	6			35599	35600	35556
04	151.657	-	F	5			35580	35588	35553
05	152.898	-	M	2		4	35560	35561	35554
06	150.455	-	M	8			35562	35563	35555
07	152.129	152.799	M	2			35564	35565	35552
08	151.713	-	M	8			-	-	35557
09	150.609	-	F	7		5	35528	35529	35515
10	152.700	-	F	4			35577	35579	35571
11	152.054	-	F	7			35530	35531	34187
12	152.818	-	M	8			35533	35534	35558
13	150.912	-	F	5		4	35594	35597	35569
14	150.223	-	F	9			35592	35593	34042
15	150.609	-	F				35583	35585	35515
16	151.321	-	F				35576	35578	35514
17	150.993	-	M				35589	35590	35559
18	152.304	152.602	M			6	35537	35538	35539
19	151.262	-	M				35535	35536	35568
20	152.406	150.258	M				35595	35596	35540
21	152.355	-	F				35532	35598	34178

Table 1 (cont.). List of moose captured during study, including moose ID# (Moose#), capture date (capdate), capture location (caplocation), number of telemetry re-locations in 1998 (98loc#), number of telemetry re-locations in 1999 (99loc#), number of telemetry re-locations in 2000 (00loc#), and total number of telemetry re-locations during study (totloc#).and status of moose at end of study (status).

Moose#	capdate	caplocation	98loc#	99loc#	00loc#	totloc#
1	12/10/96	ELK CR. BURN	-	-	-	0
2	12/10/96	KENNEDY CR.	-	-	-	0
3	12/16/97	ELK CR. BURN	25	27	7	59
4	12/18/97	ELK CR. BURN	24	27	6	57
5	12/18/97	ELK CR. BURN	24	17	-	41
6	12/18/97	BEAR CR.	24	24	7	55
7	12/18/97	BEAR CR.	12	23	6	41
8	12/18/97	BEAR CR.	23	24	6	53
9	12/19/97	UNION PK.	9	-	-	9
10	12/19/97	UNION PK.	25	27	6	58
11	12/19/97	UNION PK.	24	25	6	55
12	12/19/97	UNION PK.	26	24	6	56
13	12/19/97	ANDERSON HILL	23	26	5	54
14	12/19/97	KENO CR.	24	27	6	57
15	02/19/99	W.FK. BEAR CR.	-	25	6	31
16	02/19/99	E. FK. BEAR CR.	-	25	6	31
17	02/19/99	W.FK. BEAR CR.	-	22	6	28
18	02/19/99	W.FK.CHAMB	-	14	-	14
19	02/19/99	W.FK. BEAR CR.	-	23	6	29
20	02/19/99	LITTLE FISH CR.	-	15	-	15
21	02/19/99	BALDY GULCH	-	21	5	26
Totals			263	416	90	769

Table 1 (cont.). List of moose captured during study, including moose ID# (Moose#), and status of moose at end of study (status), chest circumference (cm), hock length (cm), neck circumference (cm), body length (cm), head length (cm), and 100% minimum convex polygon (MCP) home range size (ha).

Moose#	status	chest	hock	neck	body	head	100% MCP
1	capture mortality						
2	hunter kill						
3	alive	177.80	73.66	62.23	274.32	66.04	2,486
4	alive	193.04	74.93	66.04	205.74	62.23	6,909
5	natural death	187.96	71.12	73.66	266.70	66.04	2,963
6	alive						3,041
7	alive						4,130
8	alive	190.50	81.28	68.58	281.94	66.04	7,477
9	natural death	187.96	74.93	71.12	266.70	68.58	-
10	alive	167.64	73.66	68.58	256.54	62.23	3,318
11	alive	182.88	72.39	62.23	271.78	63.50	4,298
12	alive	193.04	74.93	76.20	279.40	66.04	6,157
13	alive						5,259
14	alive	198.12	71.12	69.85	269.24	58.42	2,040
15	alive						4,021
16	alive						3,817
17	alive						4,293
18	hunter kill						1,797
19	alive						2,234
20	lost collar						-
21	alive						2,642

measured. Data were collected at 118 moose locations from 9 June through 20 July 1999.

Although not a random sample, these plots represented over 25% of all moose locations at the time vegetation sampling began, and an attempt was made to sample locations from as many different portions of the study area as possible. This was a purely descriptive exercise since these data were not compared to availability or vegetation data from elk locations. Of particular interest were the presence and use of understory shrub species, not recognized in the Landsat TM vegetation mapping of the study area.

Willow, alder, serviceberry (*Amelanchier alnifolia*), and red osier dogwood were the most common tall shrubs at moose locations, occurring in 51%, 48%, 44%, and 35% of plots, respectively (Figure 4). False huckleberry (*Menziesia ferruginea*), Rocky Mountain maple (*Acer glabrum*), elderberry (*Sambucus racemosa*), and mountain ash (*Sorbus scopulina*) were least common, occurring in 34%, 27%, 14%, and 11% of plots, respectively (Figure 4). Heaviest use of shrubs was observed on red osier dogwood, serviceberry, and willow, while alder, elderberry, and false huckleberry were used least at moose locations (Figure 5). Tree species and size classes present at moose locations are difficult to summarize. However, all 6 size classes of Douglas fir and lodgepole pine from 2-6" and 6-12" dbh were the only species found in greater than 40% of plots (Table 2). All ponderosa pine and cottonwood size classes were found at less than 10% of moose locations measured.

Moose Habitat Use

Logistic regression was used to identify variables that best explained moose resource selection. Before the modeling procedure we tested the selected set of topographic and vegetation variables for covariance using Spearman bivariate correlation test within SPSS.

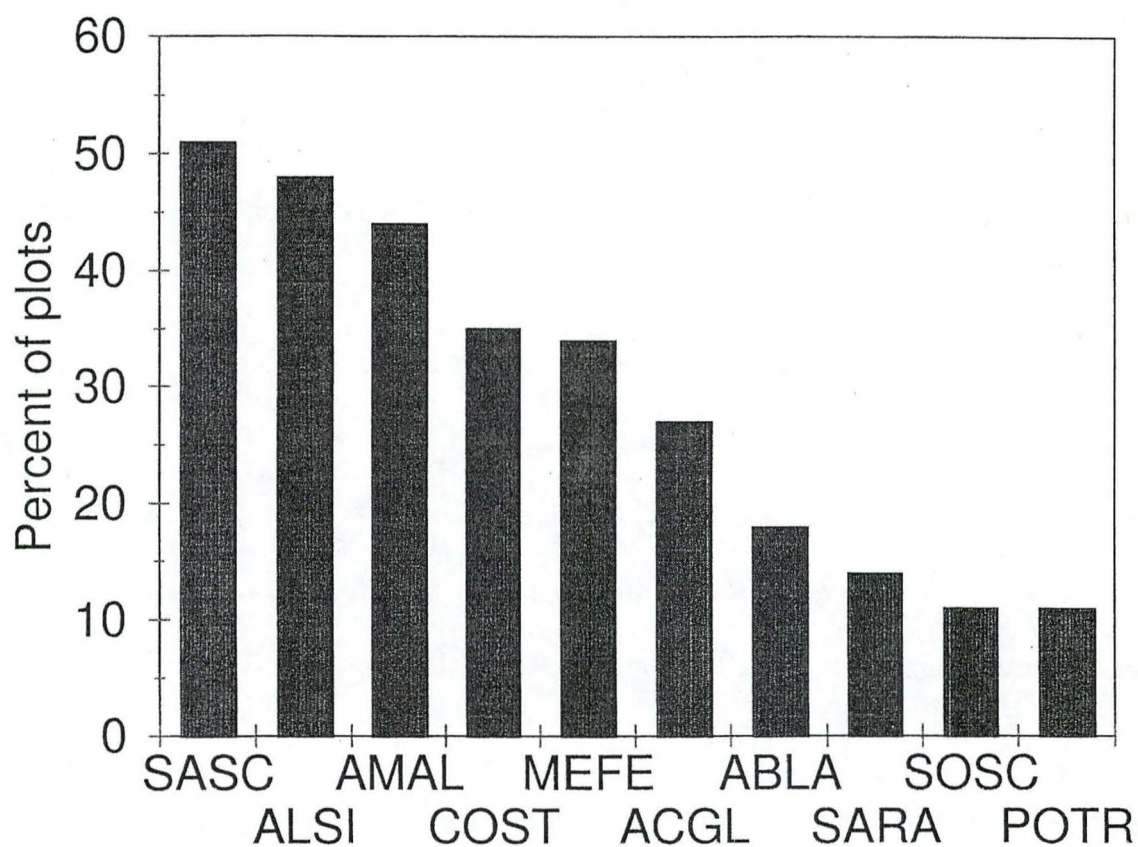


Figure 4. Percent of vegetation plots at moose locations containing browse species. SASC = *Salix scouleriana*, ALSI = *Alnus sinuata*, AMAL = *Amelanchier alnifolia*, COST = *Cornus stolonifera*, MEFE = *Menziesia ferruginea*, ACGL = *Acer glabrum*, ABLA = *Abies lasiocarpa* (saplings), SARA = *Sambucus racemosa*, SOSC = *Sorbus scopulina*, POTR = *Populus tremuloides*

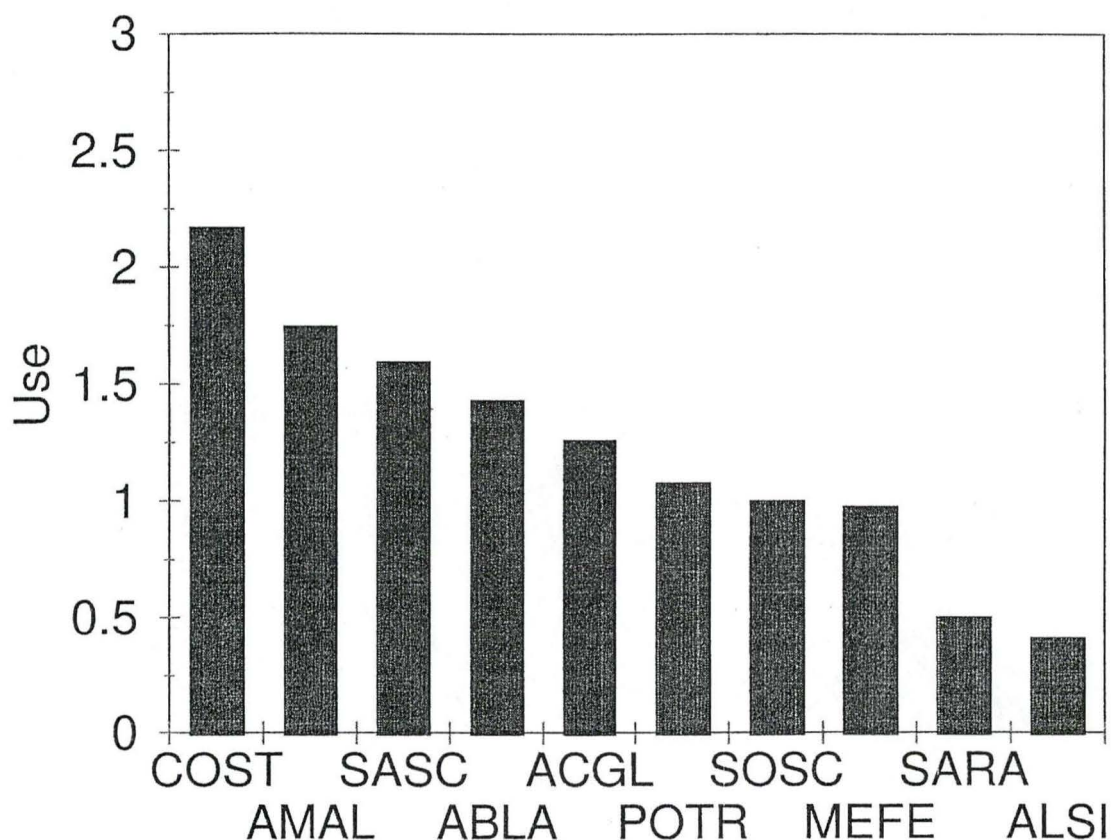


Figure 5. Level of browse use (0 = no use, 3 = highest use) on browse species in vegetation plots at moose locations. SASC = *Salix scouleriana*, ALSI = *Alnus sinuata*, AMAL = *Amelanchier alnifolia*, COST = *Cornus stolonifera*, MEFE = *Menziesia ferruginea*, ACGL = *Acer glabrum*, ABLA = *Abies lasiocarpa* (saplings), SARA = *Sambucus racemosa*, SOSC = *Sorbus scopulina*, POTR = *Populus tremuloides*.

Table 2. Trees, by species and size class found at a sample of moose locations. PICO = *Pinus contorta*, PIEN = *Picea engelmannii*, ABLA = *Abies lasiocarpa*, LAOC = *Larix occidentalis*, PSME = *Pseudotsuga menziesii*, PIPO = *Pinus ponderosa*, POTR = *Populus tremuloides*; <4 ft = <1.2 m, 0-1 in = 0-2.5 cm, 1-2 in = 2.5-5.0 cm, 2-6 in = 5.0-15.2 cm, 6-12 in = 15.2-30.5 cm, >12 in = > 30.5 cm.

Tree species and size class	% of plots	mean #/plot
PICO1 (sapling, <4 ft)	16.38%	0.94
PICO2 (0-1 in)	19.83%	1.09
PICO3 (1-2 in)	35.34%	1.64
PICO4 (2-6 in)	53.45%	7.41
PICO5 (6-12 in)	49.14%	4.03
PICO6 (> 12 in)	18.10%	0.36
PIEN1 (sapling, <4 ft)	31.90%	1.20
PIEN2 (0-1 in)	24.14%	1.06
PIEN3 (1-2 in)	29.31%	1.27
PIEN4 (2-6 in)	26.72%	1.91
PIEN5 (6-12 in)	18.10%	0.66
PIEN6 (> 12 in)	14.66%	0.37
ABLA1 (sapling, <4 ft)	38.79%	3.29
ABLA2 (0-1 in)	31.90%	1.82
ABLA3 (1-2 in)	26.72%	1.85
ABLA4 (2-6 in)	31.03%	2.50
ABLA5 (6-12 in)	22.41%	0.63
ABLA6 (> 12 in)	10.34%	0.20
LAOC1 (sapling, <4 ft)	9.48%	0.45
LAOC2 (0-1 in)	15.52%	0.53
LAOC3 (1-2 in)	19.83%	0.60
LAOC4 (2-6 in)	31.03%	1.85
LAOC5 (6-12 in)	23.28%	0.64
LAOC6 (> 12 in)	16.38%	0.45
PSME1 (sapling, <4 ft)	64.66%	11.21
PSME2 (0-1 in)	58.62%	5.41
PSME3 (1-2 in)	60.34%	4.10
PSME4 (2-6 in)	74.14%	7.02
PSME5 (6-12 in)	54.31%	1.77
PSME6 (> 12 in)	43.10%	1.04
PIPO1 (sapling, <4 ft)	2.59%	0.04
PIPO2 (0-1 in)	1.72%	0.02
PIPO3 (1-2 in)	5.17%	0.07
PIPO4 (2-6 in)	6.03%	0.34
PIPO5 (6-12 in)	2.59%	0.03
PIPO6 (> 12 in)	0.86%	0.05
POTR1 (sapling, <4 ft)	12.07%	0.99
POTR2 (0-1 in)	12.93%	0.72
POTR3 (1-2 in)	12.07%	0.60
POTR4 (2-6 in)	12.07%	1.24
POTR5 (6-12 in)	4.31%	0.18
POTR6 (> 12 in)	0.86%	0.02

ELEV was removed from all modeling because it was correlated with both V3 (dry coniferous forest) and V4 (wet coniferous forest). V3 and V4 were also correlated, but were left in the model because they represent the dominant vegetation types in the study area. V6 (lakes, ponds) was removed because it did not occur near either moose or random locations.

Logistic models were created for each season (winter, spring, summer, rut, and hunting season) and yearlong (Table 3). An additional model for fall (rut and hunting season combined) was created for comparison with a moose model within the moose/elk study area. R^2 values for all RSF's were low, ranging from 0.06 - 0.19. DIST_HY appeared in all models while SLOPE and V2 (mesic shrubs) each appeared in all but one model. Moose selection was always negatively correlated with increasing distance from water and increasing slope, and positively correlated with mesic shrubs.

In the yearlong RSF, V2 (mesic shrubs) and DIST_HY (distance to water) were the first variables entered in the model during the forward stepwise procedure. Negative correlations with V1 (non-forest) and NE_NESS and positive correlations with V5 (aspen) and V7 (rock) helped separate yearlong moose locations from random locations.

In the winter, V4 (wet coniferous forest; negative coefficient) and V2 (mesic shrub; positive coefficient) were the first two variables entered. A positive correlation with V5 (aspen) and negative correlations with DIST_HY (distance to water), V1 (non-forest), and SLOPE (slope) also helped describe winter selection by moose.

The spring model had the lowest r^2 value. Negative correlations with NE_NESS (northeast-ness) and DIST_HY (distance to water) and positive correlations with V2 (mesic shrub) and V3 (dry coniferous forest) helped explain spring habitat selection. V4 (wet coniferous

Table 3. Variables in yearlong and seasonal RSF's for moose, in the order they entered the forward stepwise logistic regression model, for the moose study area. V1 = grassland, V2 = mesic shrub, V3 = dry coniferous forest, V4 = wet coniferous forest, V5 = aspen, V7 = rock, DIST_HY = distance to mapped water, SLOPE = slope, NE_NESS = aspect (degrees from northeast), DIST_RD = distance to nearest road of any type, R3_DIST = distance to nearest road open to motorized vehicles.

	Yearlong	Winter	Parturition	Summer	Rut	Hunt	(Fall)
n =	753	339	64	199	105	46	151
r ²	0.13	0.19	0.06	0.07	0.16	0.10	0.15
1 st variable	V2 (+)	V4 (-)	NE_NESS (-)	V4 (+)	SLOPE(-)	V2 (+)	SLOPE (-)
2 nd variable	DIST_HY (-)	V2 (+)	DIST_HY (-)	NE_NESS (-)	V7(+)	DIST_RD (+)	DIST_RD (+)
3 rd variable	SLOPE (-)	V5 (+)	V2 (+)	V7 (+)	DIST_RD (+)	DIST_HY (-)	V2 (+)
4 th variable	V1 (-)	DIST_HY (-)	V3 (+)	V1 (-)	R3_DIST (+)	SLOPE (-)	DIST_HY (-)
5 th variable	NE_NESS (-)	V1 (-)		SLOPE (-)	V2 (+)		V5 (+)
6 th variable	V5 (+)	SLOPE (-)		DIST_HY (-)	DIST_HY (-)		
7 th variable	V7 (+)						

forest) was the first variable entered into the summer moose model, however at this time of year, the correlation was positive.

Summer moose locations were also positively correlated with V7 (rock), and negatively correlated with NE_NESS (northeast-ness), V1 (non-forest) SLOPE (slope), and DIST_HY (distance to water).

Road variables appeared in all fall models for moose selection (rut, hunt, fall). Rut locations of moose were positively correlated with DIST_RD (distance to any road) and DIST_R3 (distance to open road) while hunting season moose locations were positively correlated with DIST_RD (distance to any road). Rut moose locations were also positively correlated with V7 (rock) and V2 (mesic shrubs) and negatively correlated with DIST_HY (distance to water). In addition to the open road variable, hunting season moose locations were positively correlated with V2 (mesic shrub), and negatively correlated with DIST_HY (distance to water) and SLOPE (slope).

Moose Use of Disturbance Classes

To answer specific questions about moose responses to forest management actions or natural disturbances, we conducted a separate analysis of moose use of 7 classes of forest disturbance. This was done for each individual radio-collared moose, because of varying availabilities of disturbance types within their home ranges. Results of these individual analyses were pooled into Table 4. Although most comparisons showed no difference between use and availability of the disturbance categories, some patterns did emerge. All moose but one had CC2 (new clearcuts) available to them ($n = 15$), yet most of those individuals used this type significantly less than predicted by availability ($P < 0.10$). Although use of this type by several

Table 4. Results of Bonferroni tests showing moose use of forest disturbance classes. Tables shows individual moose ID numbers that used each class more than it was available (+), less than it was available (-), and equal to its availability (=).

Disturbance Class	+ ($P \leq 0.10$)	- ($P \leq 0.10$)	= ($P \leq 0.10$)
old clearcuts (n=9)	11, 12		06,07,08,10,13,21
new clearcuts (n=15)		03,04,06,07,08,15, 19,21	10,11,12,13,14,16,17
select cuts (n=15)		16	03,04,06,07,08,11,12, 13,14,15,17,19,21
new burn (n=4)			04,07,16
old burn (n=5)	06	03	05, 08
uncut, non-forest (n=11)			03,04,08,10,11,12,13, 14,21
uncut, forest (n=16)	03, 06		04,05,06,07,08,10,11, 12,13,14,15,17,19,21

moose was not significantly different than availability, their trend of use was always equal to or less than its availability. Two moose used old clearcuts greater than availability (Figures 6 and 7), 3 times greater by one moose and 2 times greater by the other. Similarly, moose #6 used the old burn (CC5) more than twice than its availability within his home range (Figure 8). Select cuts (CC3), natural openings (CC6), and uncut forest (CC7) were mostly used near their availabilities by individual moose.

Spatial Separation of Moose and Elk

The area of overlap of moose and elk home ranges was 9,027 ha. This area contained 286 locations from 9 radio-collared moose and 294 locations from 23 cow elk in 3 distinct herd home ranges (Edge et al 1985, Burcham et al. 1998). To look at how moose and elk used a common area, we looked at spatial separation of the two species within this area. When seasonal moose locations were overlayed on the elk location density map, several patterns were noted. The general trend, for all 6 bi-monthly periods, was for moose to use areas with no elk locations greater than the availability of these areas, and to use the high elk location density areas less than availability (Figures 9-14). Significant differences ($P < 0.10$) occurred in winter comparisons (November-December, January-February, March-April). The areas with no elk locations were used significantly more than availability ($P < 0.10$) by moose for the November-December and January-February comparison. The highest elk location density areas, those with >15 locations for a 250 m radius area, were used significantly less than availability by moose. Even in summer (May-October), when differences were not significant, the highest 2 elk location density classes were always used less than their availability by moose.

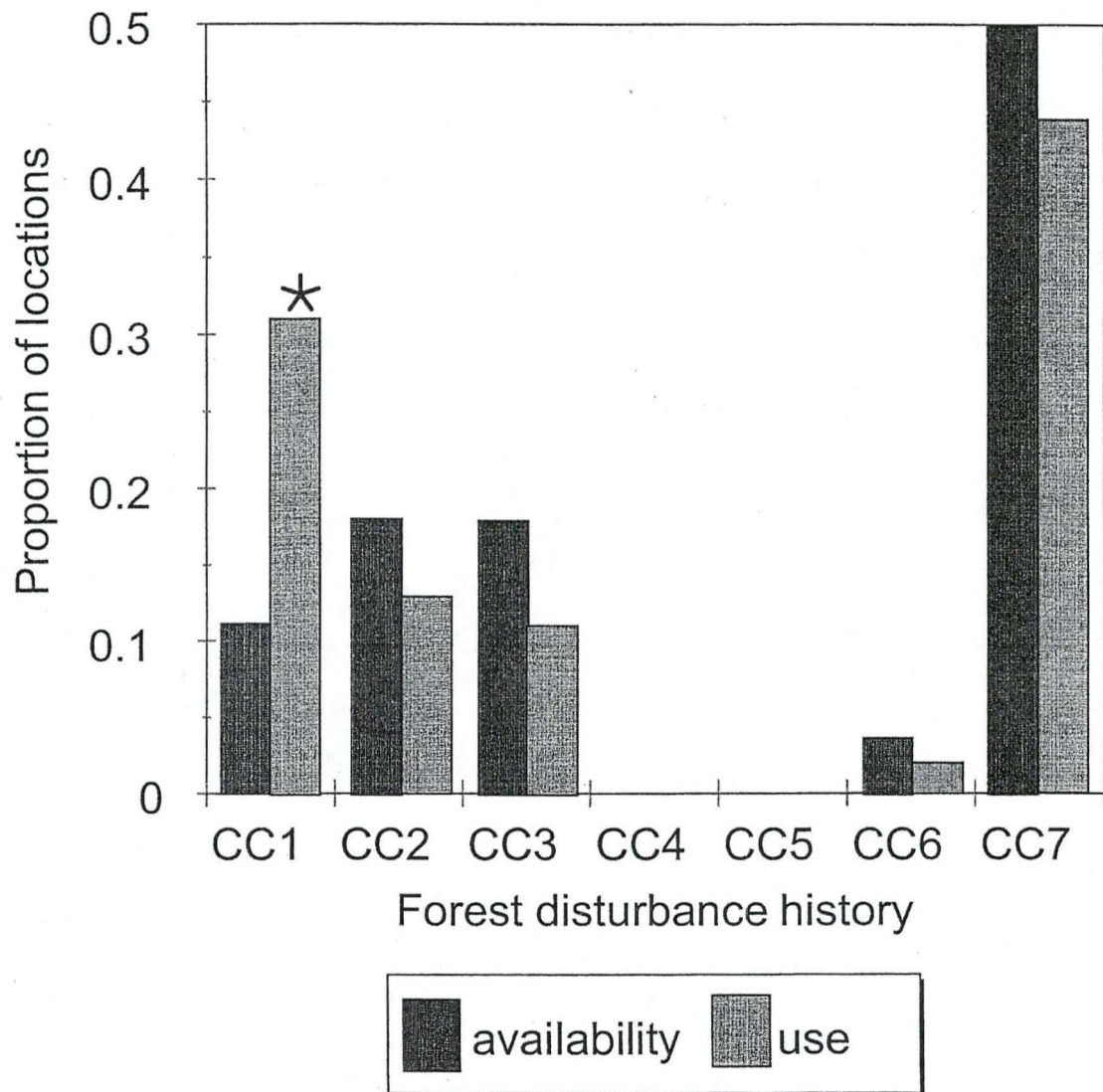


Figure 6. Use of forest disturbance history classes by moose #11. (CC1 = old clearcuts, CC2 = new clearcuts, CC3 = select cuts, CC4 = new burn, CC5 = old burn, CC6 = uncut, non-forest, CC7 = uncut, forest).

* - Significantly different than available ($P < 0.10$)

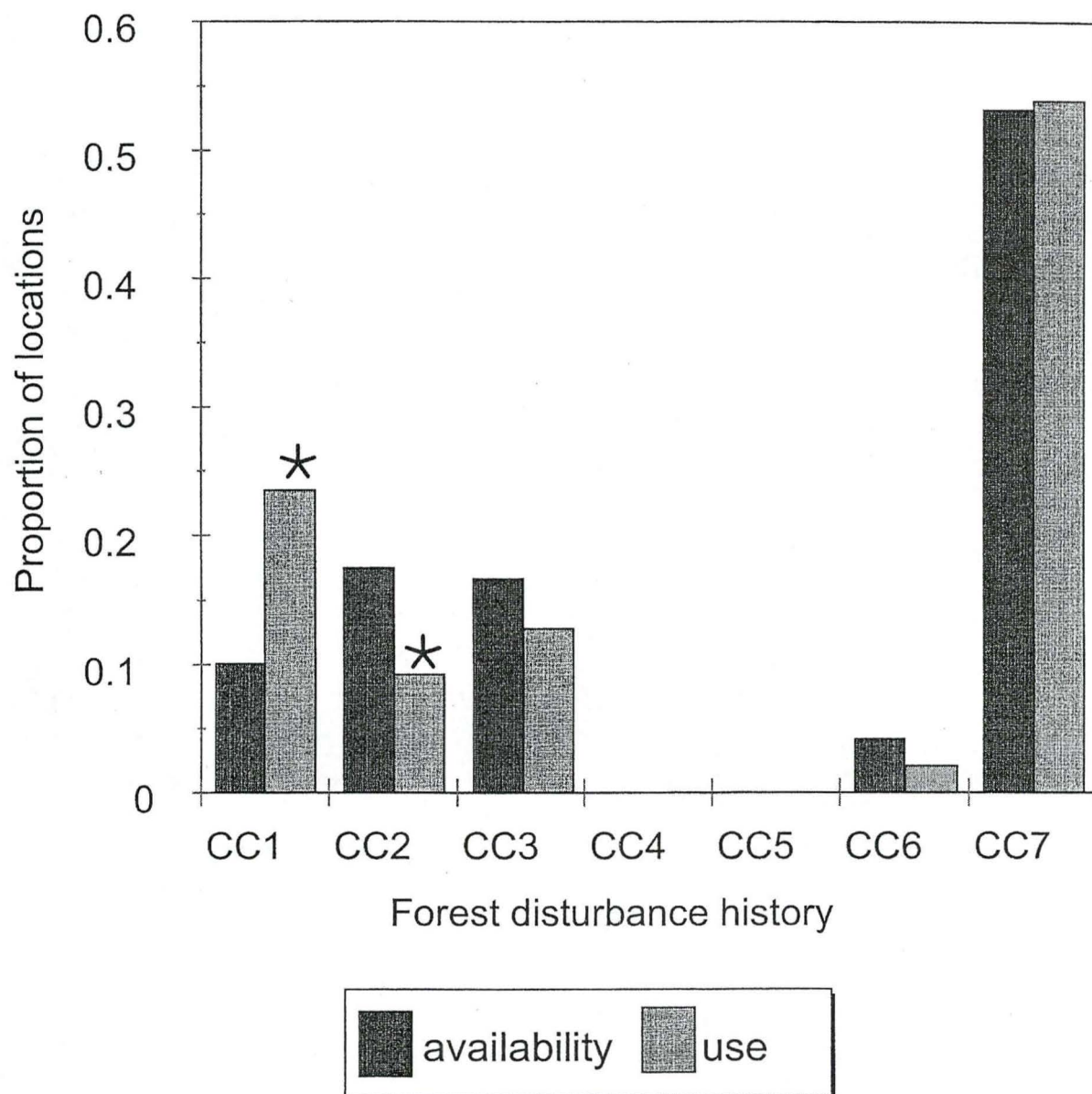


Figure 7. Use of forest disturbance history classes by moose #12. (CC1 = old clearcuts, CC2 = new clearcuts, CC3 = select cuts, CC4 = new burn, CC5 = old burn, CC6 = uncut, non-forest, CC7 = uncut, forest).

* - Significantly different than available. ($P < 0.10$)

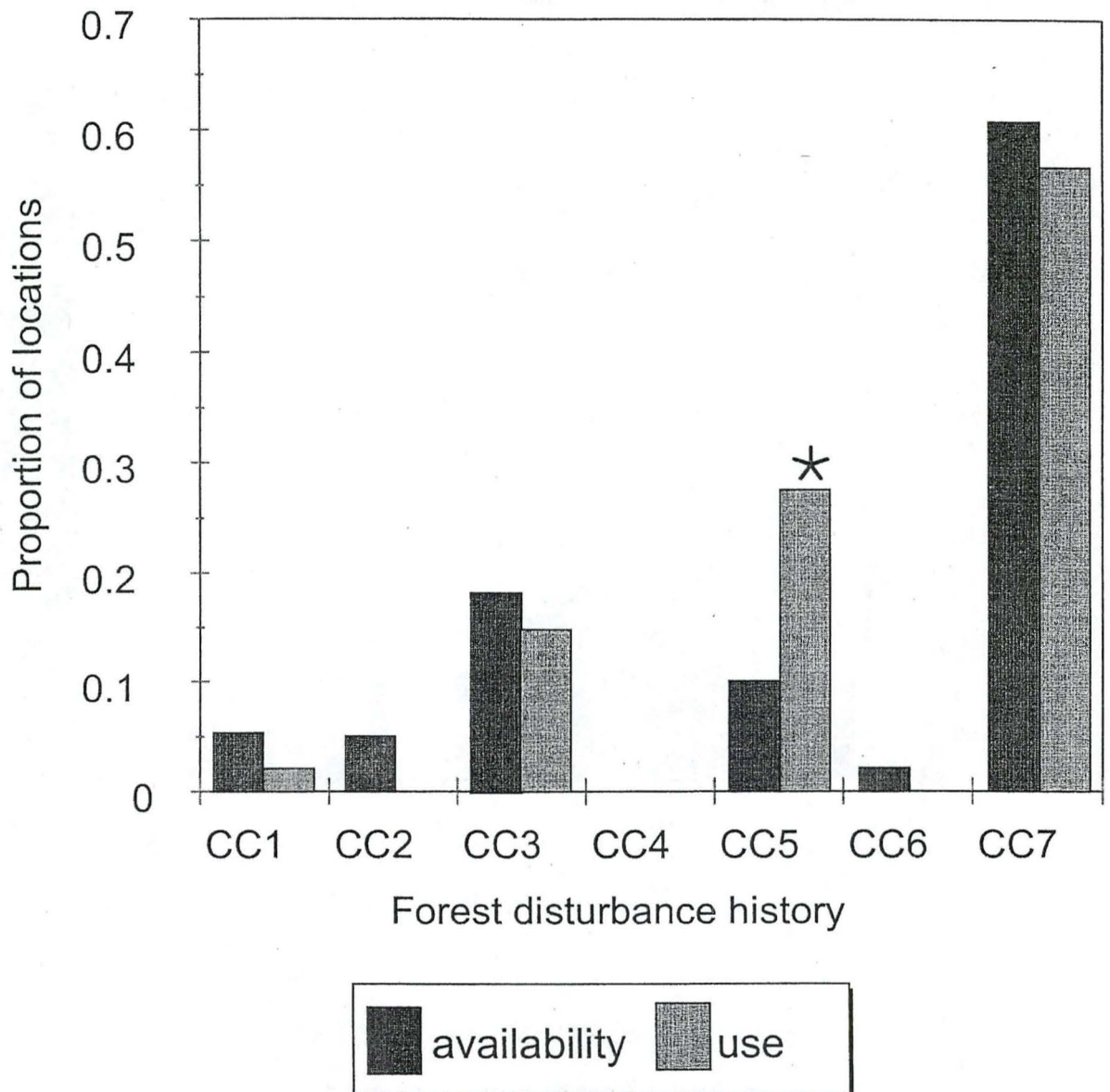


Figure 8. Use of forest disturbance history classes by moose #06. (CC1 = old clearcuts, CC2 = new clearcuts, CC3 = select cuts, CC4 = new burn, CC5 = old burn, CC6 = uncut, non-forest, CC7 = uncut, forest).

* - Significantly different than available ($P < 0.10$)

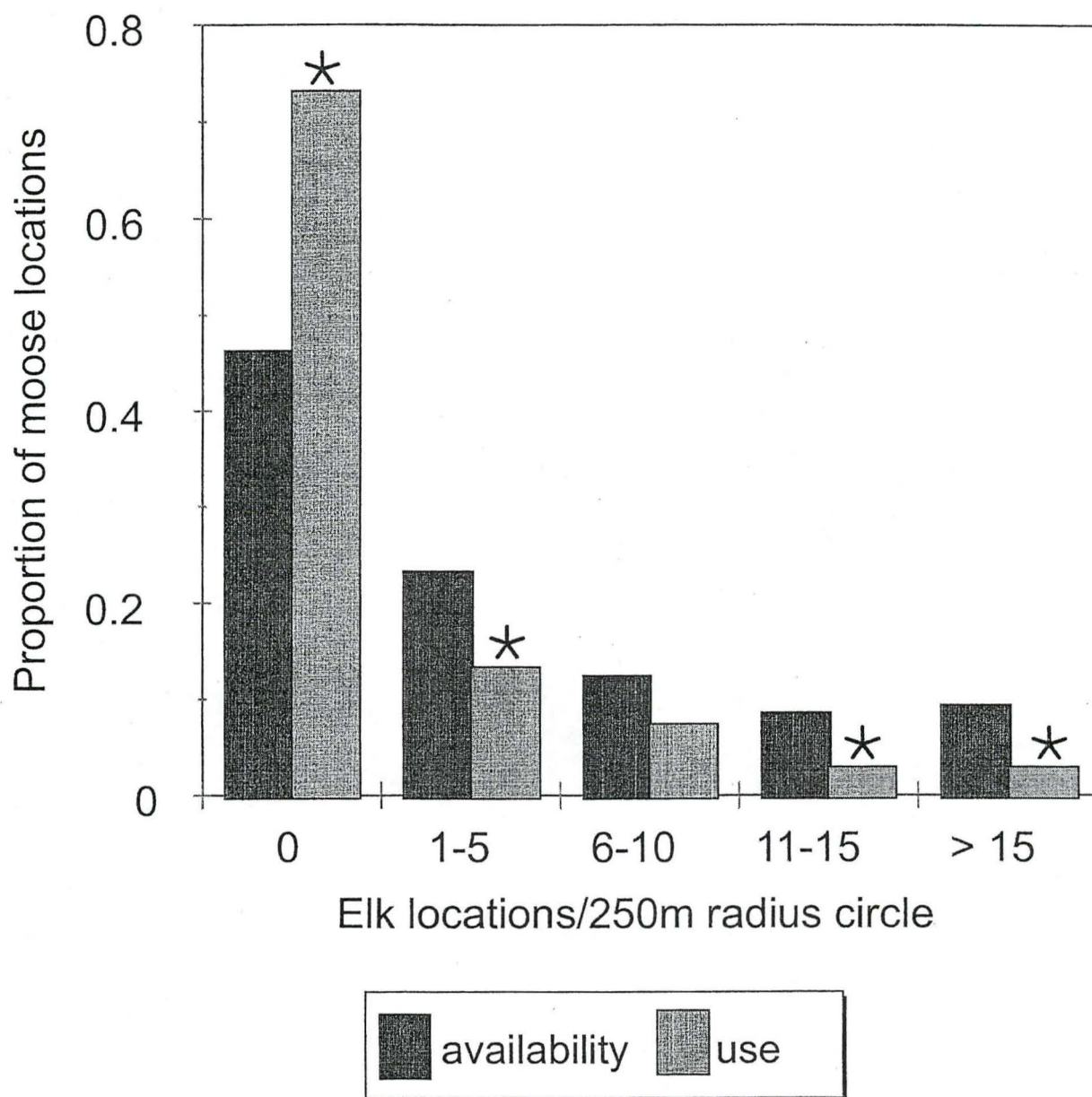


Figure 9. Moose use of elk location density classes for January - February.

* - Significantly different than available ($P < 0.10$)

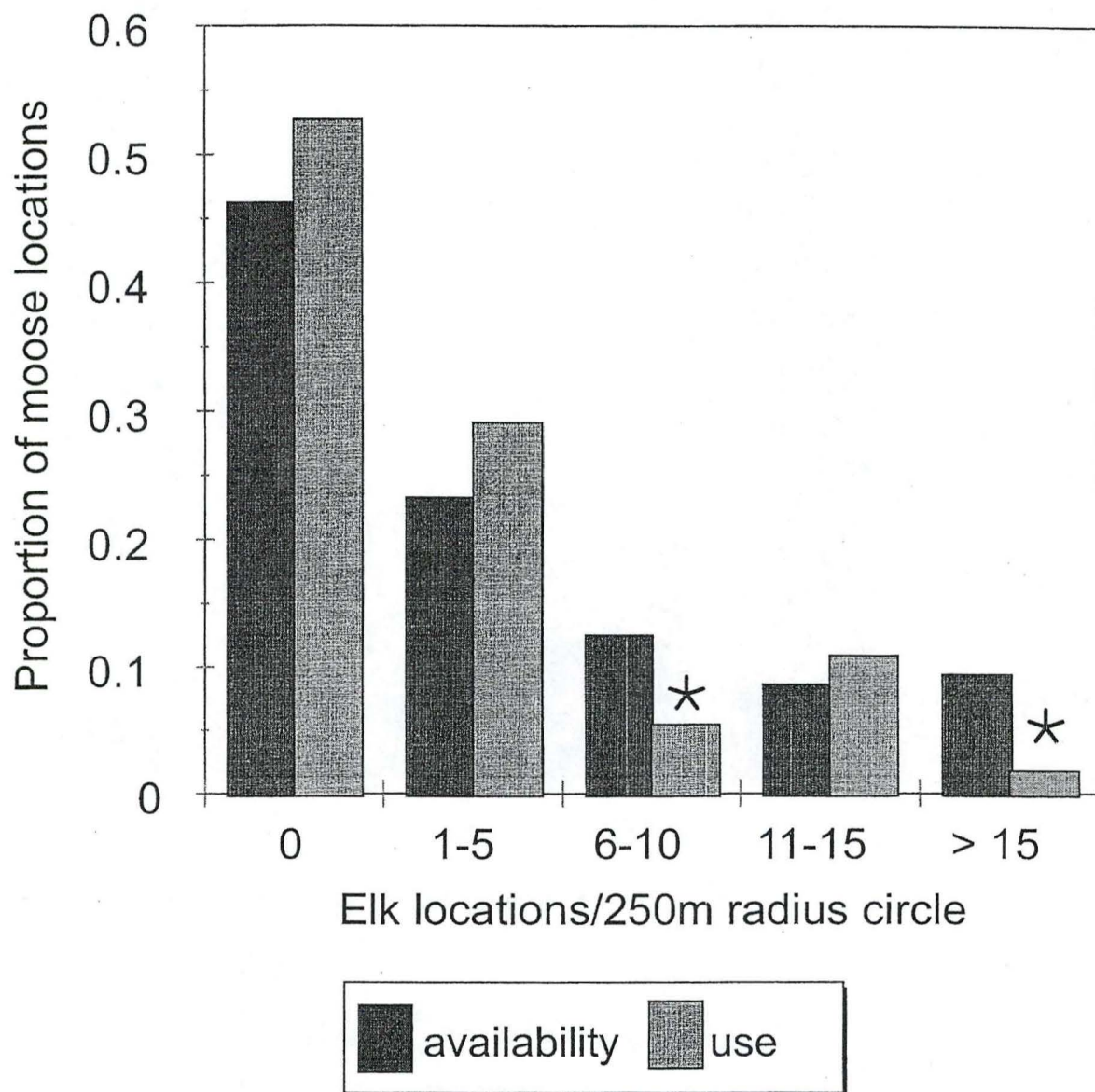


Figure 10. Moose use of elk location density classes for March - April.

* - Significantly different than available ($P < 0.10$)

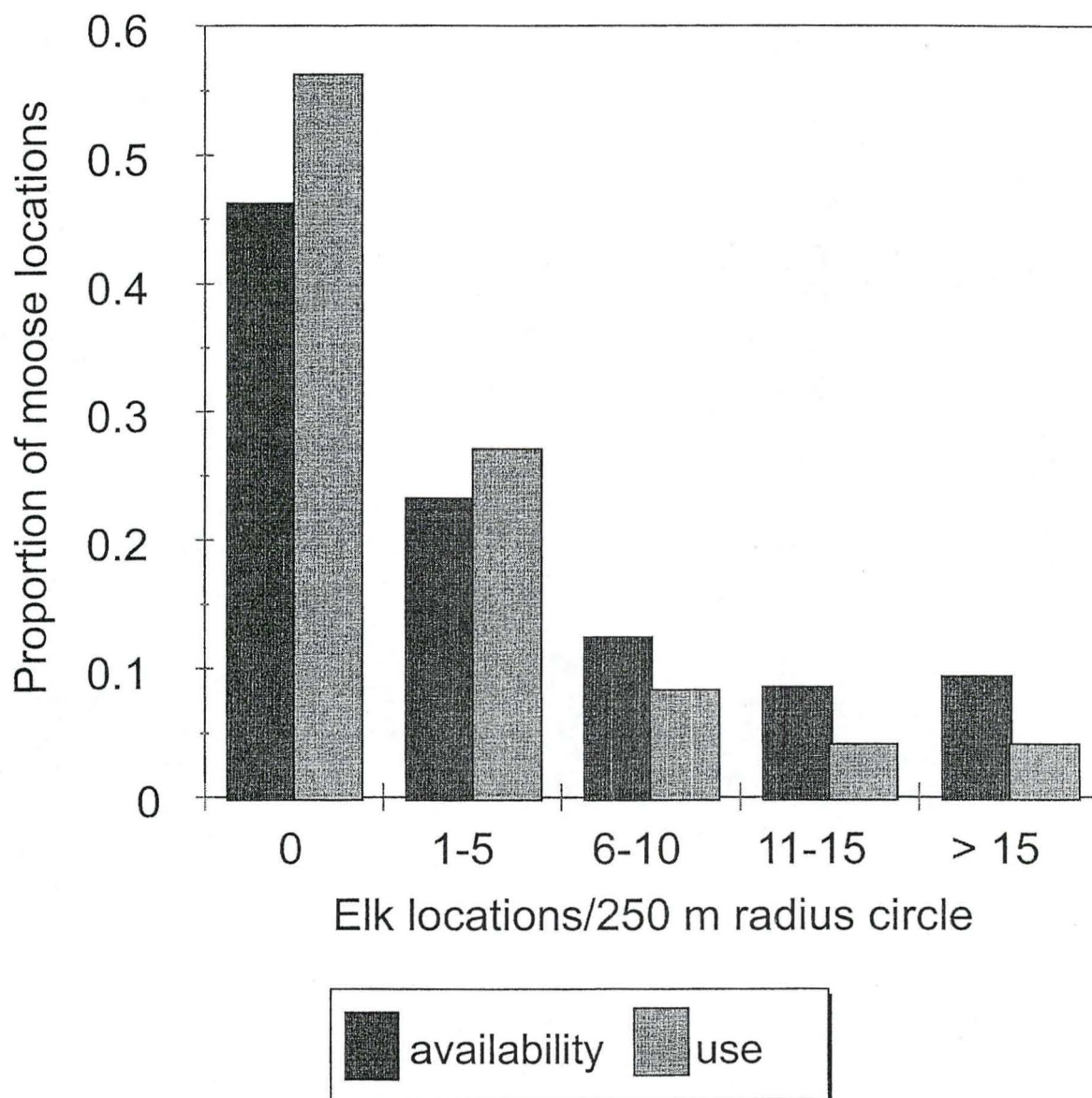


Figure 11. Moose use of elk location density classes for May - June.

* - Significantly different than available ($P < 0.10$)

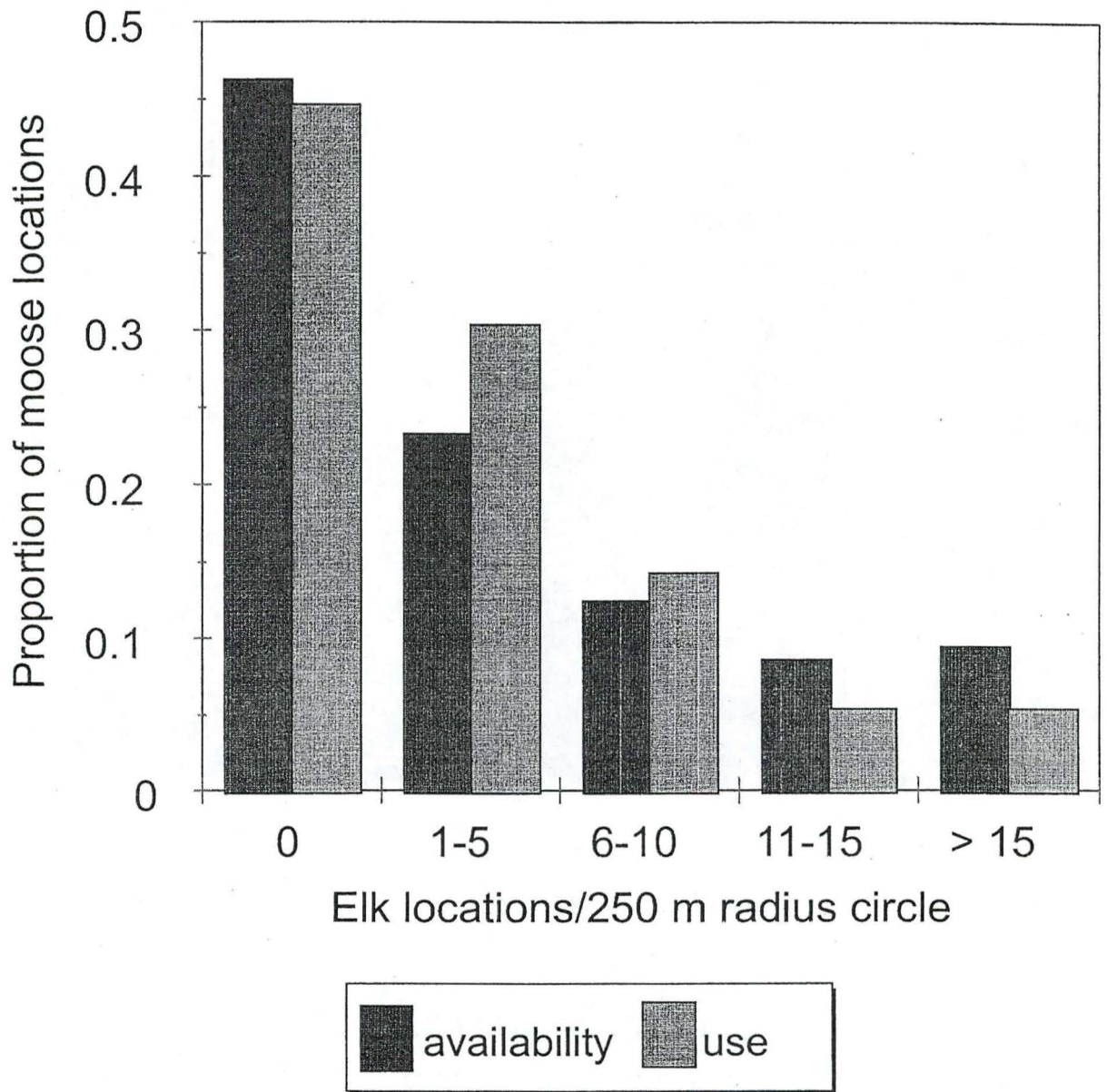


Figure 12. Moose use of elk location density classes for July - August.

* - Significantly different than available ($P < 0.10$)

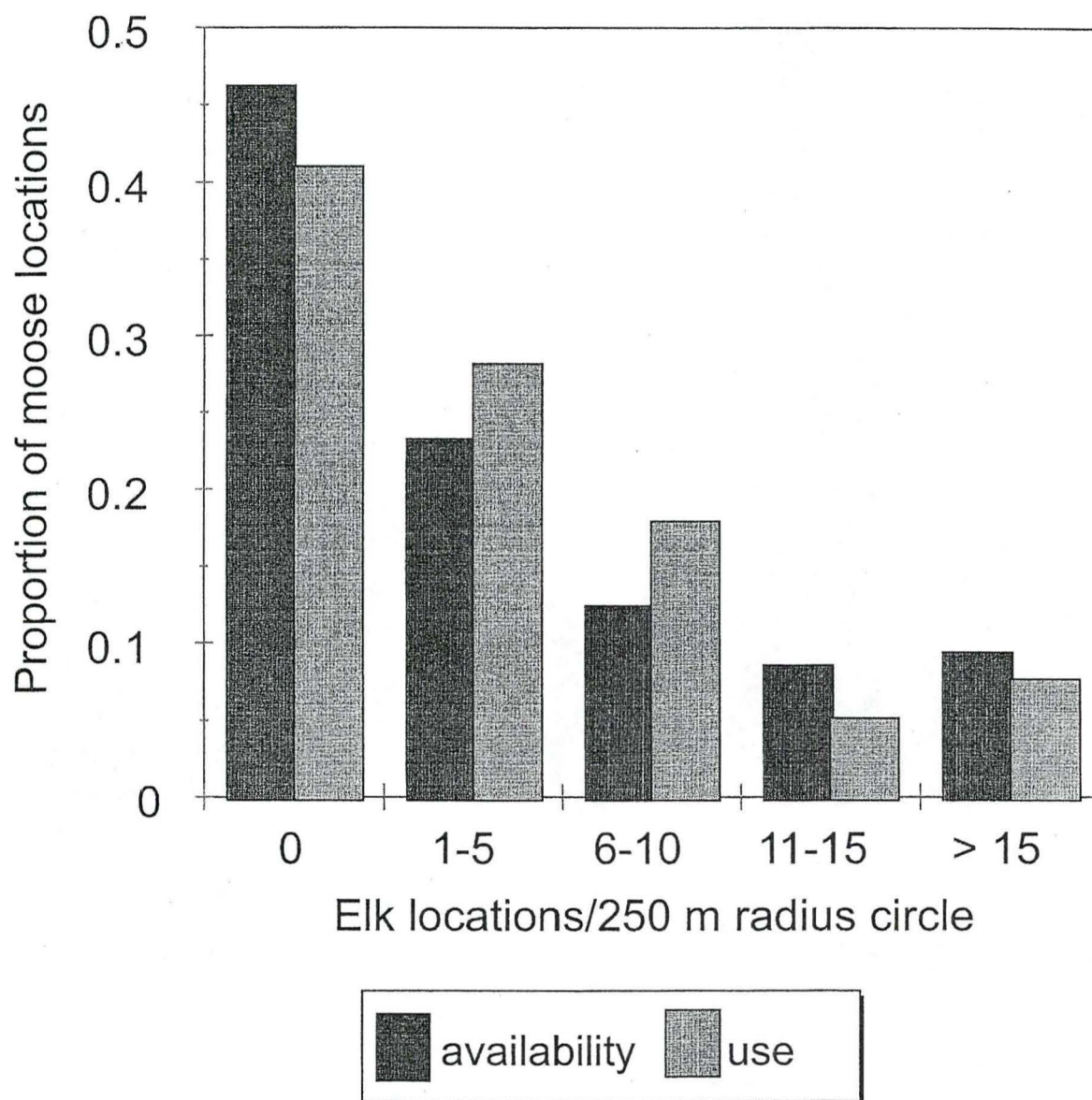


Figure 13. Moose use of elk location density classes for September - October.

* - Significantly different than available ($P < 0.10$)

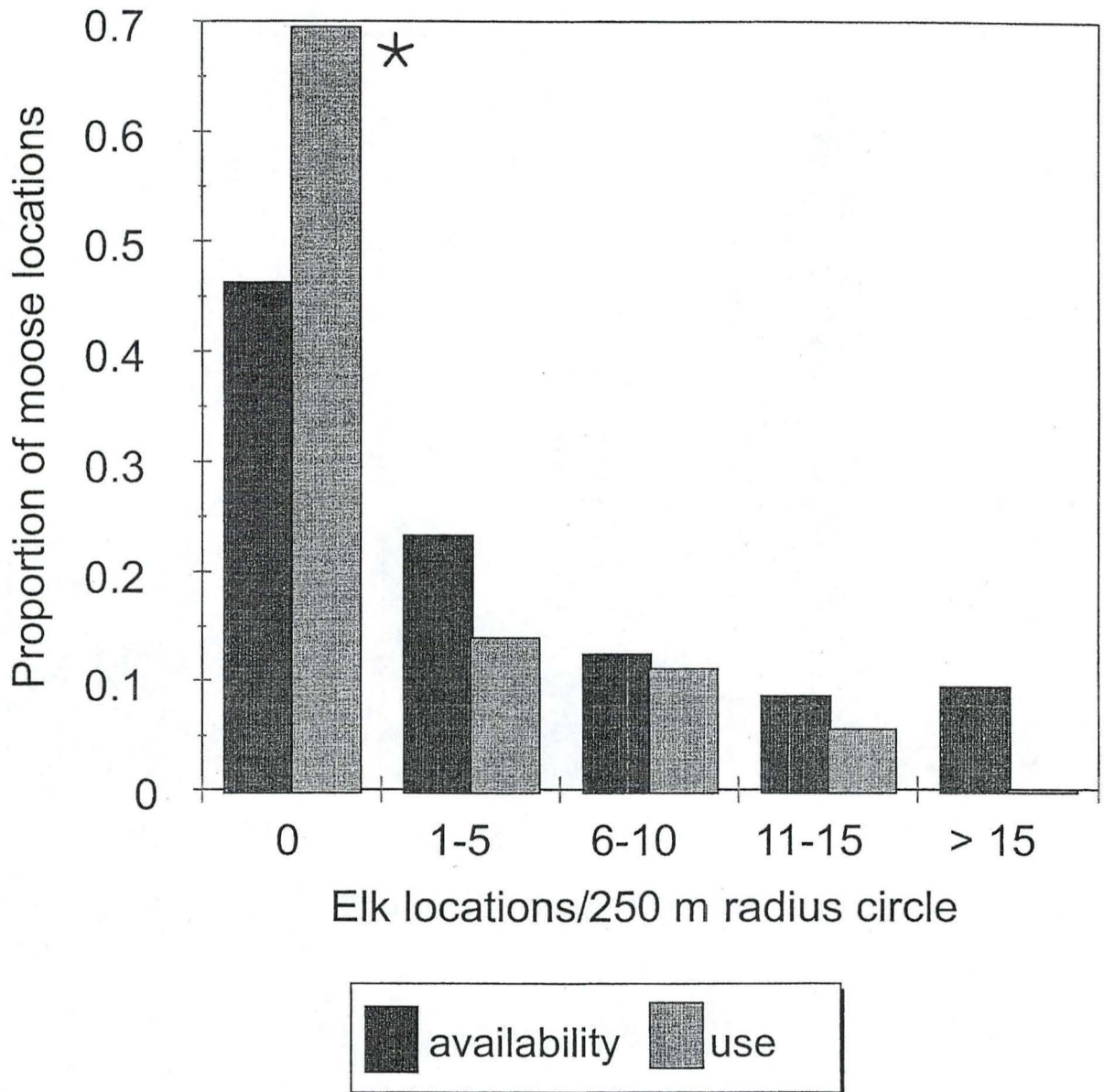


Figure 14. Moose use of elk location density classes for November - December.

* - Significantly different than available ($P < 0.10$)

Moose and Elk Habitat Use

After identifying spatial relationships between sympatric elk and moose, we used logistic regression to identify habitat features that helped explain how moose and elk use the same landscape (Table 5). Correlated variables were first removed from further modeling. ELEV (elevation) was again correlated with both V3 (dry coniferous forest) and V4 (wet coniferous forest), and was removed from further modeling. V3 (dry coniferous forest) and V4 (wet coniferous forest) were also correlated, but left in the model, because they both represented the dominant forest types on the landscape. V5 (aspen forest) and V6 (lakes, ponds) were removed because they did not occur at moose, elk, or random locations within the moose/elk study area. Yearlong and seasonal RSF's were developed for each species, according to the availability of data, and according to the biological seasons for each species. No model was developed for elk in winter because we collected few winter locations during the elk study. We did not create a moose model for moose hunting season (15 September - Sunday after Thanksgiving), because hunting pressure by the six permit holders per year was very light when distributed over the Garnets, and probably did not influence habitat selection by moose. The sample of moose locations during the general elk and deer hunting season (5 weeks, ending the Sunday after Thanksgiving; generally starts the 3rd week in October) was not large enough to build a reliable model, so those locations were combined with rut locations to produce a fall season model.

R^2 values were low from resulting models. Significant variables from models and the signs of their coefficients were included in Table 5 to identify the most important variables to moose and elk distributions and the direction of their influence. DIST_HY (distance to water) appeared in more models than any other variable (5 of 10) and was always negatively correlated

Table 5. Variables in yearlong and seasonal resource selection functions for moose and elk, in the order they entered the forward stepwise logistic regression model, for the moose/elk study. V2 = mesic shrub, V3 = dry coniferous forest, V4 = wet coniferous forest, V7 = rock, DIST_HY = distance to mapped water, SLOPE = slope, NE_NESS = aspect (degrees from northeast), R3_DIST = distance to nearest road open to motorized vehicles.

	moose					elk				
	yearlong	winter	spring	summer	fall	yearlong	spring	summer	rut	hunt
n =	286	154	33	71	28	294	63	81	74	69
r ²	0.04	0.21	0.09	0.02	0.44	0.08	0.25	0.03	0.11	0.24
1 st variable	DIST_HY (-)	DIST_HY (-)	DIST_R3(-)	V2 (-)	V4(+)	DIST_HY (+)	V4 (-)	SLOPE (-)	V4 (+)	V2 (-)
2 nd variable		V4 (-)		V3 (-)	SLOPE (-)	V2 (-)	DIST_HY (+)		V7 (+)	V4 (+)
3 rd variable		V2 (+)		NE_NESS (-)		SLOPE (-)				DIST_HY (+)

with moose locations and positively correlated with elk locations. That is, moose locations tended to be closer to mapped water while elk locations tended to be farther. This was the most important variable in separating yearlong and winter moose locations and yearlong elk locations from random points. It also helped predict parturition and hunting season elk locations. Several vegetation variables entered the moose and elk models. V4 (wet coniferous forest) was used less than expected by moose in winter but more than expected during the rut. The same type was avoided by elk during spring, yet it was selected during the rut and hunting season. V2 (mesic shrub) types were selected by moose in winter yet avoided in summer. Mesic shrub types were negatively correlated with moose locations in the yearlong and hunting season models. SLOPE (slope) was negatively correlated with moose and elk locations in several RSF's, with both species selecting for more gentle terrain.

Use of Security Attributes by Moose and Elk

Bonferonni confidence interval tests comparing moose and elk use of distance-to-road categories showed differences between non-hunting season and hunting season locations for both species (Figures 15 and 16). Outside of hunting season, use of areas within 100 m of any road by moose was nearly more than expected ($P < 0.10$), and elk use of this area was less than expected ($P < 0.10$). Both species used the other distance to road categories generally as expected, with the exception of elk making significantly greater use of areas from 100-200 m from roads ($P < 0.10$). However, during the respective hunting season for each species, both species used areas less than 100 m from any road less than predicted ($P < 0.10$). Moose appeared to use areas 100-500 m from any road greater than expected during hunting season, although these differences were not significant. Elk use of these categories was similar to their availability. The moose use

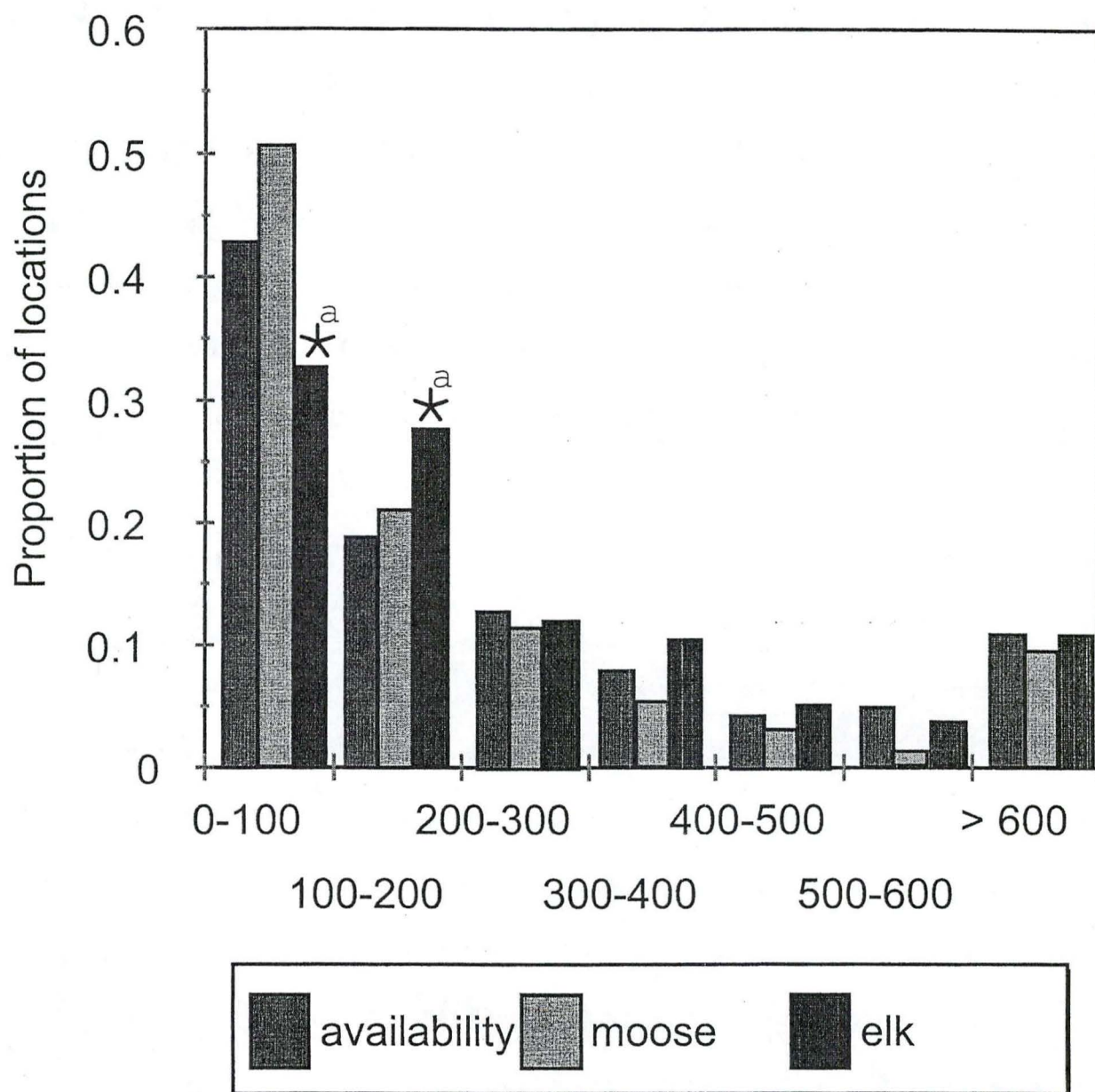


Figure 15. Use of distance-to-any-road categories (m) by moose and elk during the non-hunting season, compared to the availability of each category.

a - Significantly different than available ($P < 0.10$)

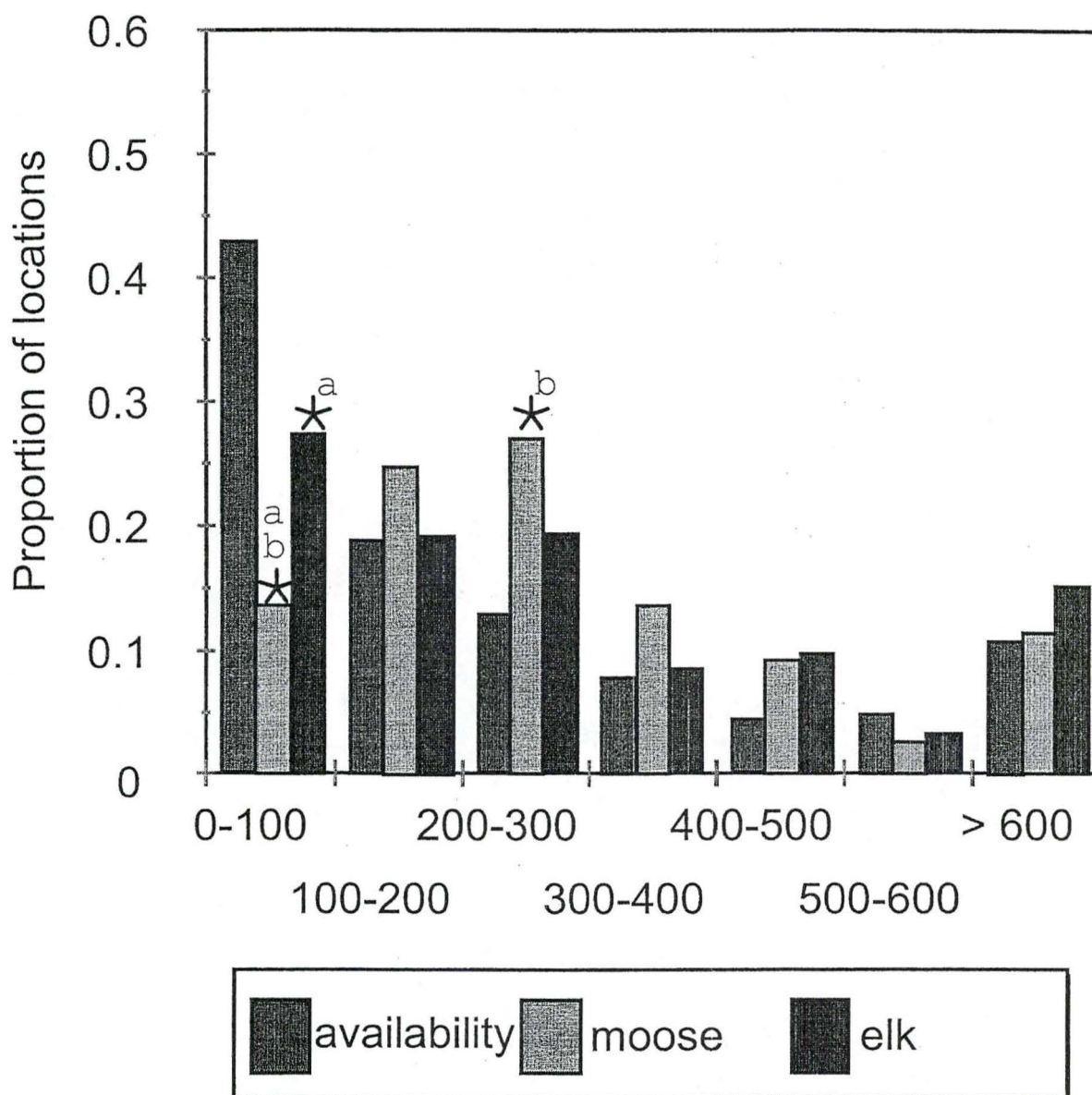


Figure 16. Use of distance-to-any-road categories (m) by moose and elk during the hunting season, compared to the availability of each category.

a - Significantly different than available ($P < 0.10$)

b - Significantly different than non-hunting season use ($P < 0.10$)

of areas less than 100 m from roads during hunting season was significantly different from their non-hunting season use, as was their increased use of areas 200-300 m from roads during hunting season. Elk use of these “distance to any road” categories was not significantly different between hunting and non-hunting seasons. However, their trend yearlong was to use areas <100 m from roads less than would be expected by their availability, and the areas >100 m from any road equal to or greater than their availability.

Distances of moose and elk to roads that were open to vehicle traffic were more difficult to interpret (Figures 17 and 18). Only 11% of the random locations fell within 1,000 m of open roads in the area of moose and elk overlap, giving little opportunity to evaluate how moose and elk react to them during the hunting and non-hunting seasons. During the non-hunting season, moose used the areas <1,000 m from open roads more than expected. Elk use of areas <2,000 m from open roads during the non-hunting season was near their availability, and almost greater than availability for areas 3,000 - 4,000 m from open roads. During hunting season, moose appeared to use the area <1,000 m, and 1,000-2,000 m from open roads at greater than expected levels, and at less than expected levels for areas 2,000 - 3,000 m from open roads. Elk use of distance to open road categories during the hunting season was similar to the non-hunting season.

Similarly, we looked at proportions of forest cover (> 39% canopy cover) within 100 ha (250 acre), 200 ha (494 acre), and 400 ha (988 acre) circles centered on moose, elk and random locations (Figures 19-21). At the smallest scale, 100 ha, the proportion of moose and elk locations with 50-75%, and > 75% forest cover did not differ from expected values ($P < 0.10$). These data show that over 35% of random points were surrounded by at least 75% forest cover, and that similarly high percentages of moose and elk locations were as well. At larger scales

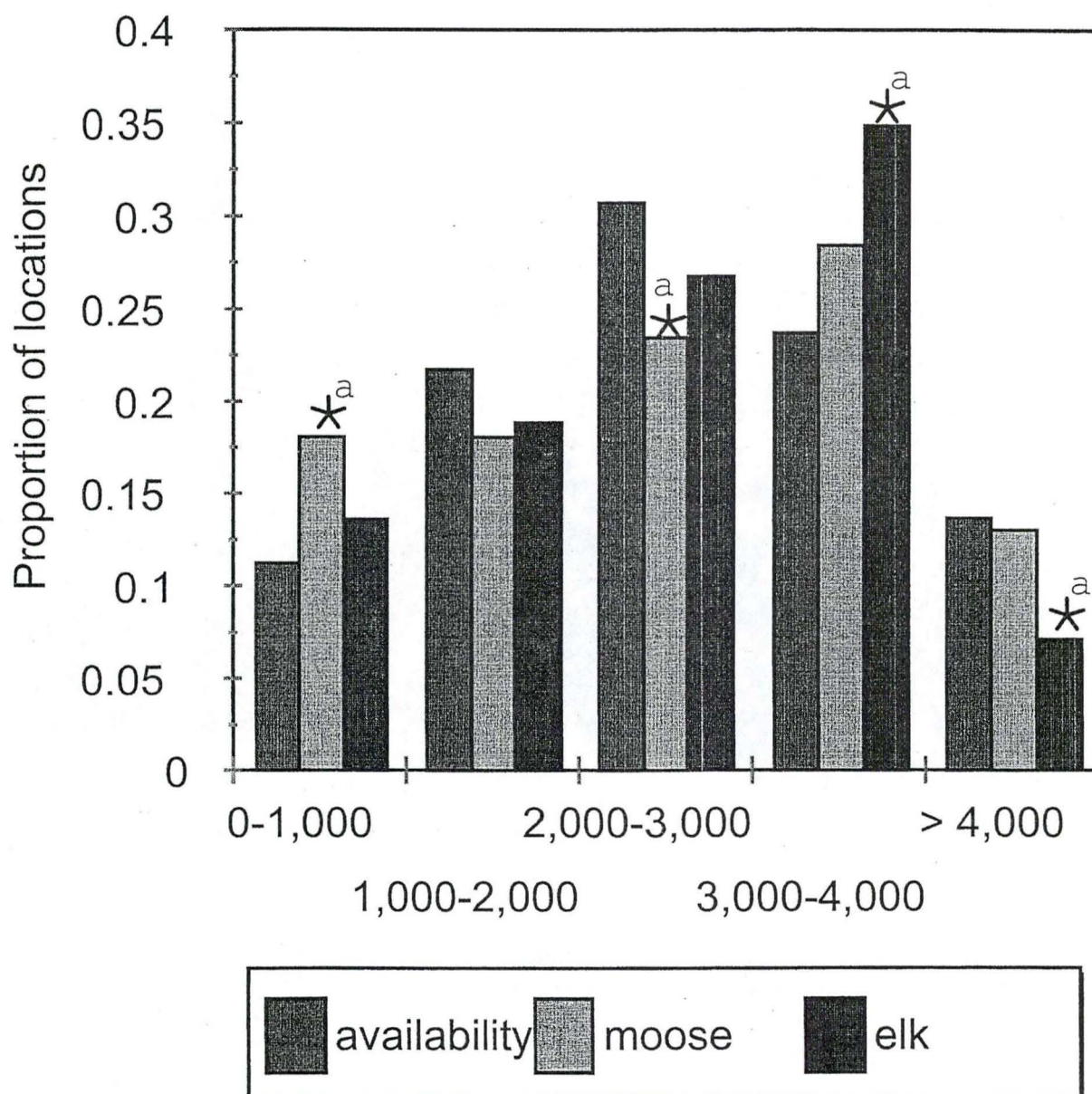


Figure 17. Use of distance-to-open-road categories (m) by moose and elk during the non-hunting season, compared to the availability of each category.

a - Significantly different than available ($P < 0.10$)

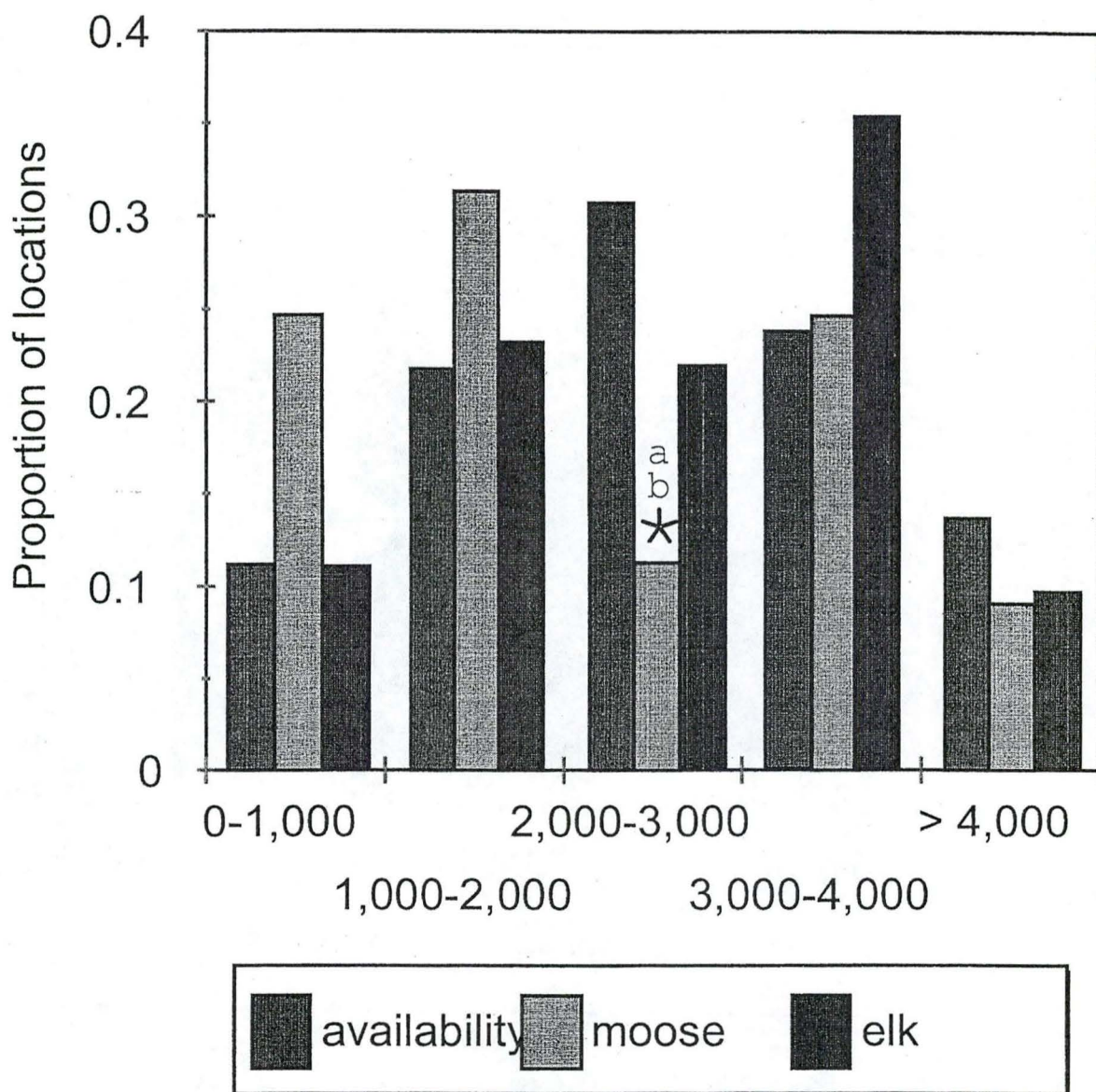


Figure 18. Use of distance-to-open-road categories (m) by moose and elk during the hunting season, compared to the availability of each category.

a - Significantly different than available ($P < 0.10$)

b - Significantly different than non-hunting season use ($P < 0.10$)

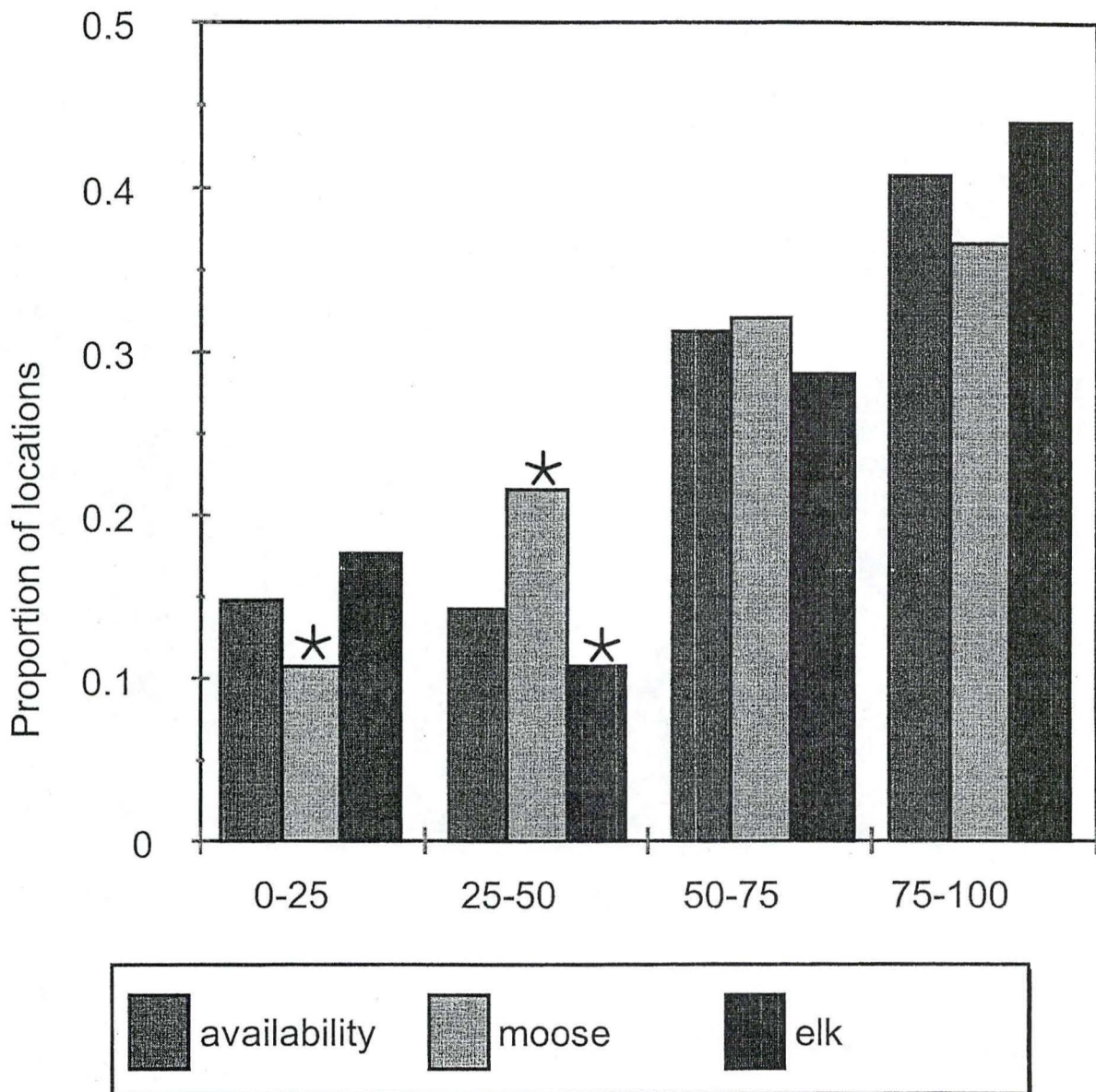


Figure 19. Moose and elk use of 4 categories representing the amount of coniferous forest within a 100 ha (250 acre) circle, surrounding moose and elk locations, compared to the availability of each category.

* - Significantly different than available ($P < 0.10$)

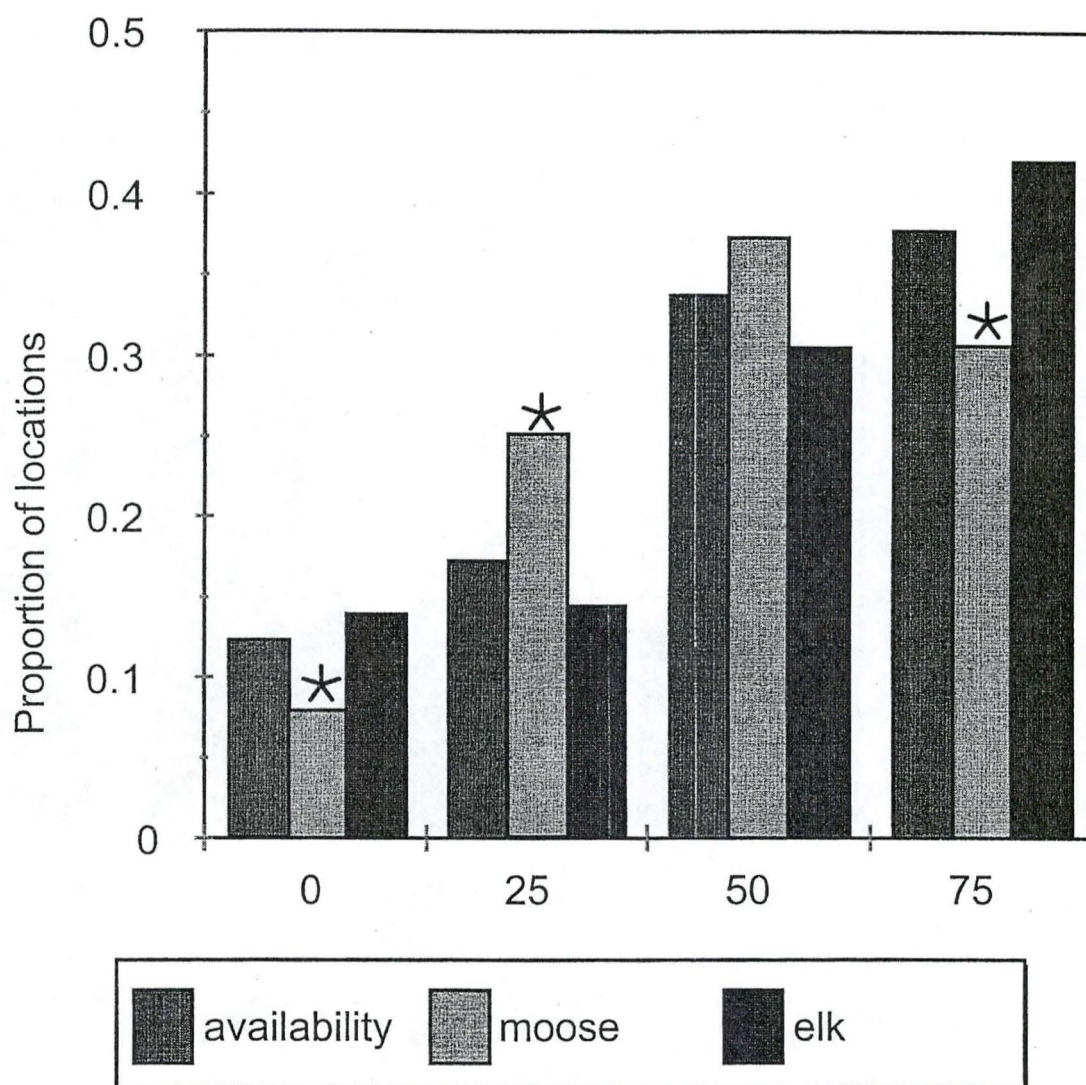


Figure 20. Moose and elk use of 4 categories representing the amount of coniferous forest within a 200 ha (494 acre) circle, surrounding moose and elk locations, compared to the availability of each category.

* - Significantly different than available ($P < 0.10$)

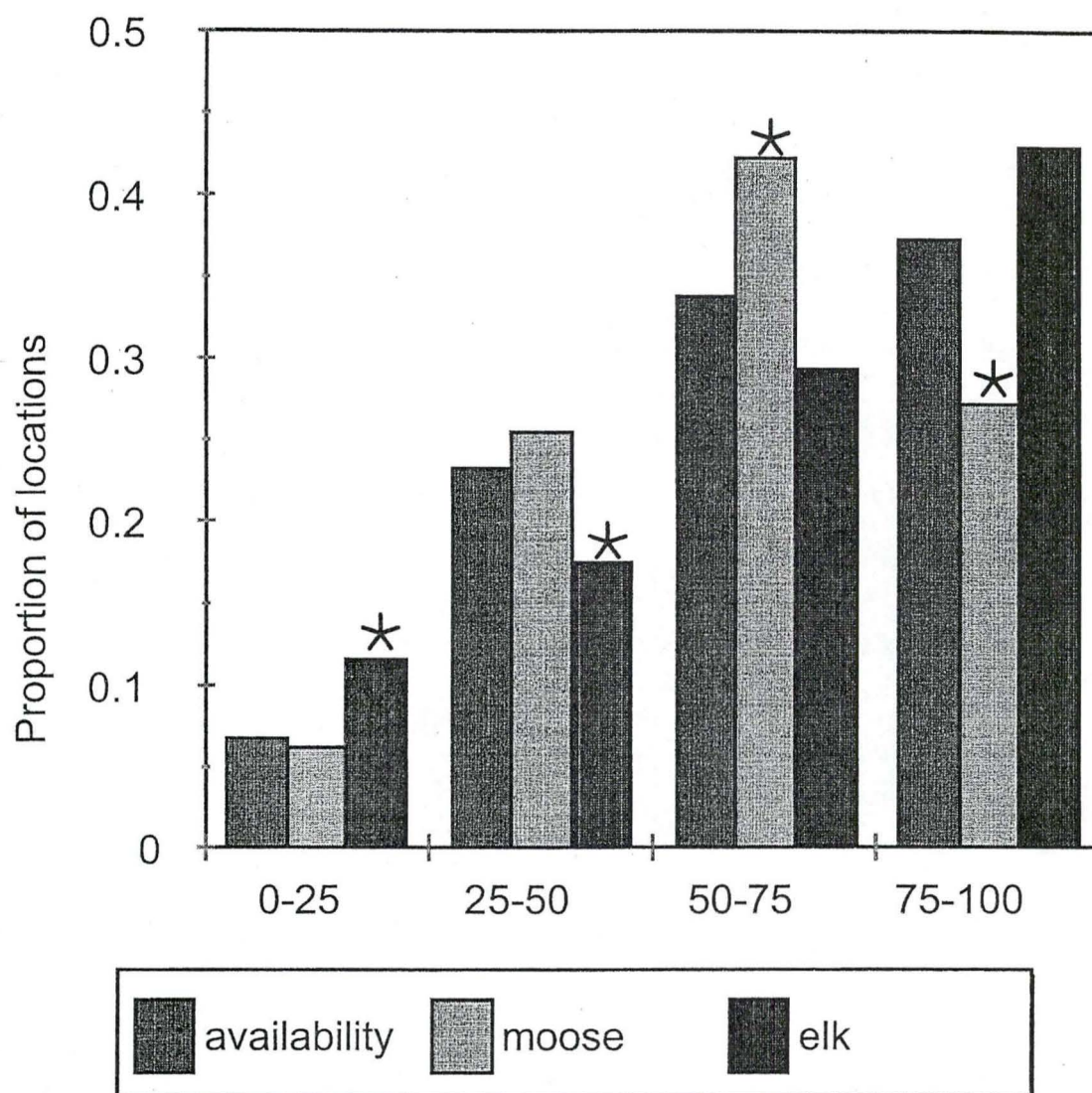


Figure 21. Moose and elk use of 4 categories representing the amount of coniferous forest within a 400 ha (988 acre) circle, surrounding moose and elk locations, compared to the availability of each category.

* - Significantly different than available ($P < 0.10$)

(200 and 400 ha), however, moose use of areas that were >75% forested was less than expected ($P < 0.10$). Even at these larger scales where moose used heavily forested areas less than availability, approximately 30% of their locations were in these areas, representing substantial use of them. At all scales, moose used either areas that were 25-50% or 50-75% forested more than they were available ($P < 0.10$).

In this same analysis, elk tended to use areas that were >75% forested more than expected, and areas 25-50% and 50-75% forested less than expected, although these differences were not significant ($P < 0.10$). When we tried this analysis counting all forest classes within the circles, even those with 10-39% canopy cover, elk use of areas that were more than 75% forested was significantly greater than expected ($P < 0.10$) at the largest scale (400 ha), but not at smaller scales.

Population Parameters

Observability - Approximately 35 % of locations were confirmed with a visual location of the animal, although visuals varied from 5% in August to 94% in December (Figure 22). Animals were most visible from the air in December and January, when canopy cover at locations was lowest and snow depth at locations was highest. Moose were least visible April through September with only about 10% of moose locations confirmed visually during this period. Moose locations obtained from March through October had the greatest overstory canopy coverage. Average snow depth at locations was 0 cm from June through October.

Moose survey - We flew from 13:09 to 15:26 on the afternoon of 5 January 2000 and from 08:35-16:10 on 6 January 2000. Weather conditions were cloudy with gusty winds on the afternoon of 5 January, and high overcast or partly cloudy and calm on 6 January. Snow covered

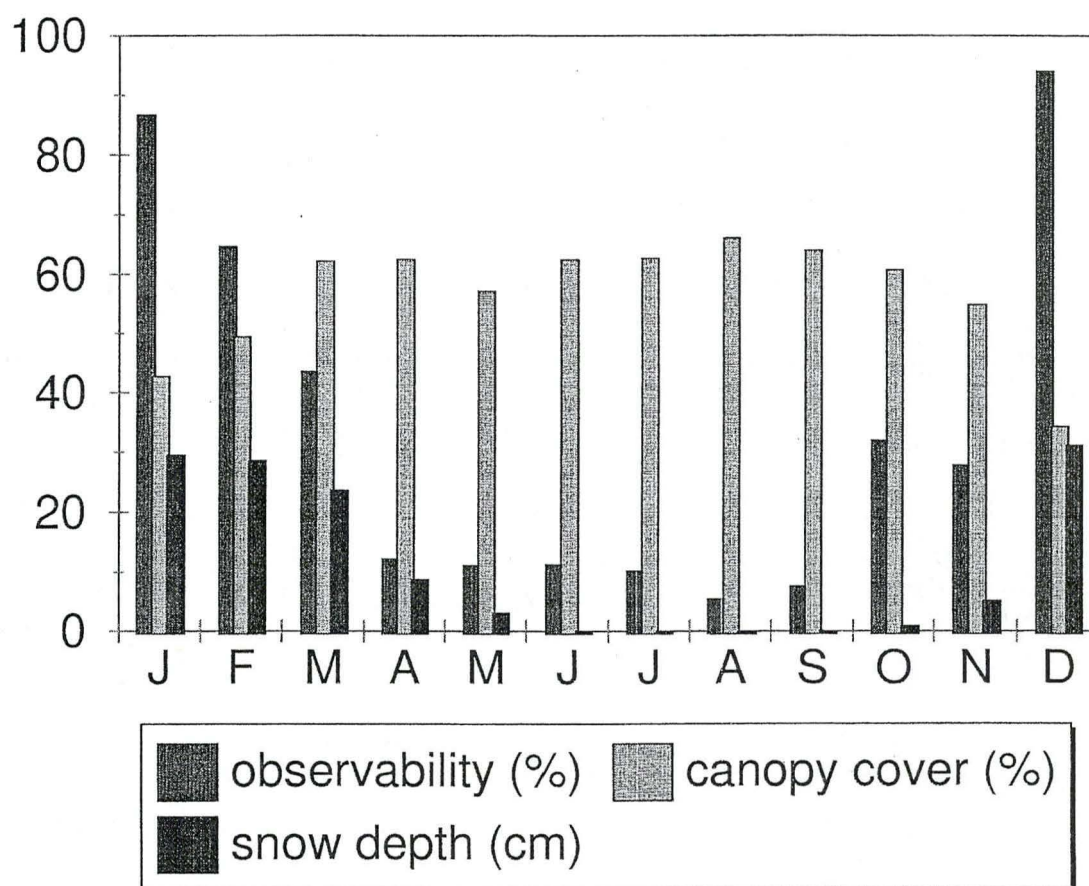


Figure 22. Monthly observability of moose (% seen) from a fixed-wing aircraft during telemetry flights, compared to the mean estimated tree canopy cover (%) and snow depth (cm) at moose locations.

the entire search area with < 31 cm at lower elevations and > 76 cm in higher elevations. Fresh snow (5-15 cm) had fallen over the area on the night of 4 January. Temperatures were between -5 and 0°C.

During 8 hours and 39 minutes of search time we observed 44 moose (Table 6). These included 19 females, 9 calves (no twins were observed), and 16 males. Although we were unable to conduct a telemetry flight immediately before or after the census, we estimated that 13 radio-collared moose were in the count area based upon observations during the count and a flight that took place on 13 January 2000. Of these radio-collared animals, we sighted 9 providing a rough Lincoln-Peterson population estimate of 64 moose for the count area (not the entire Garnet Range). If calves (which had no chance to be marked) were removed from the calculation, we would estimate 51 adult moose in the same area.

Calf production - Attempts were made each spring to count calves accompanying radio-collared female moose (Table 7). Observability of females from the air was low in late spring and summer, so an effort was made to view these animals from the ground. Only one calf was observed during observations of all 6 females in 1998, averaging only 17 calves:100 cows. However, some calves could have been lost before sightings were made. One female in 1998 was not observed until October. In 1999, 7 calves were observed with 9 different females, averaging 78 calves:100 cows. Of the 5 females with calves, 2 had twins providing an estimated twinning rate of 40%.

Mortality - Three deaths of radio-collared moose were recorded. Not enough evidence was available to determine the cause of death for the female that died in spring 1998. The mortality occurred near calving season and the female had tested positive for pregnancy at

Table 6. Distribution and classification of moose observed from a helicopter on 5 - 6 January 2000, by count units, in the eastern Garnet Mountains. See Figure 3 for count unit locations.

	Baldy	Union	Chamberlain	Kennedy	Fish	S. Elk	Deep	All Units
Total Moose	6	3	10	15	2	4	4	44
Females	2	1	5	7	1	1	2	19
Calves	1	1	0	4	0	1	2	9
Males	3	1	5	4	1	2	0	16
Moose/hr	4.1	3.7	4.8	8.4	1.9	4.1	8.3	5.0
Collars seen (%)	2/2 (1.0)	1/1 (1.0)	4/5 (0.80)	1/2 (0.50)	1/1 (1.0)	0/1 (0.0)	0/1 (0.0)	9/13 (0.69)

Table 7. Observed calf production for 1998 and 1999, and the dates that visuals were first obtained for the female and calf/calves.

female ID #	1998		1999	
	date seen	# calves	date seen	# calves
03	16 July	0	11 June	1
04	16 July	0	18 June	2
10	1 July	0	23 June	1
11	22 June	0	24 June	2
13	12 October	0	25 June	0
14	30 June	1	9 July	0
15	-	-	24 June	0
16	-	-	17 June	1
21	-	-	14 June	0
total		1		7
mean		0.17		0.78

capture the previous December. A bear hunter reported the carcass of a radio-collared bull moose in Kennedy Creek in October 1999. Inspection of the carcass and a brief necropsy indicated no wound from a bullet or an arrow. Further inspection of the site revealed a large area of disturbed soil < 10 m from the carcass. It appears that this young bull broke his neck in a fight with another bull. The other mortality was a male harvested by a hunter in September 1999, the fall following capture. None of the 5 radio-collared bull moose that entered the 1998 hunting season were harvested by hunters and 1 of the 7 that entered the 1999 hunting season was harvested by a hunter

Home ranges - Yearlong minimum convex polygon (MCP) home ranges were calculated for all moose with at least 26 radio locations (Figure 23). Moose 100% MCP's averaged 4,068 ha (Table 1). Mean home range size was slightly larger for males (4,328 ha) than for females (3,866 ha). Five of the 16 moose used in these calculations were tracked for one year, and had only 26 to 31 locations each. Moose that were tracked for 2 years had 41 to 58 locations each.

Blood and fecal analyses - Blood and fecal samples from some of the captured moose were analyzed for disease and parasites. Blood samples for 9 moose were negative for brucellosis, bluetongue, infectious bovine rhinotracheitis, bovine virus diarrhea, para influenza-3, bovine leukosis virus, and leptospirosis. Fecal analyses on samples from 10 moose revealed *Nematodirella* spp. in 2 males. Eight other moose tested negative for worm ova and coccidian oocysts. Fecal samples were inadvertently frozen, therefore, could not be tested for lungworms (*Dictyocaulus viviparus*). No tests were performed for flukes (*Fascioloides* spp.). Results of these tests and complete blood assays for each individual moose are on file at the Montana Department of Fish, Wildlife, and Parks Lab in Bozeman.

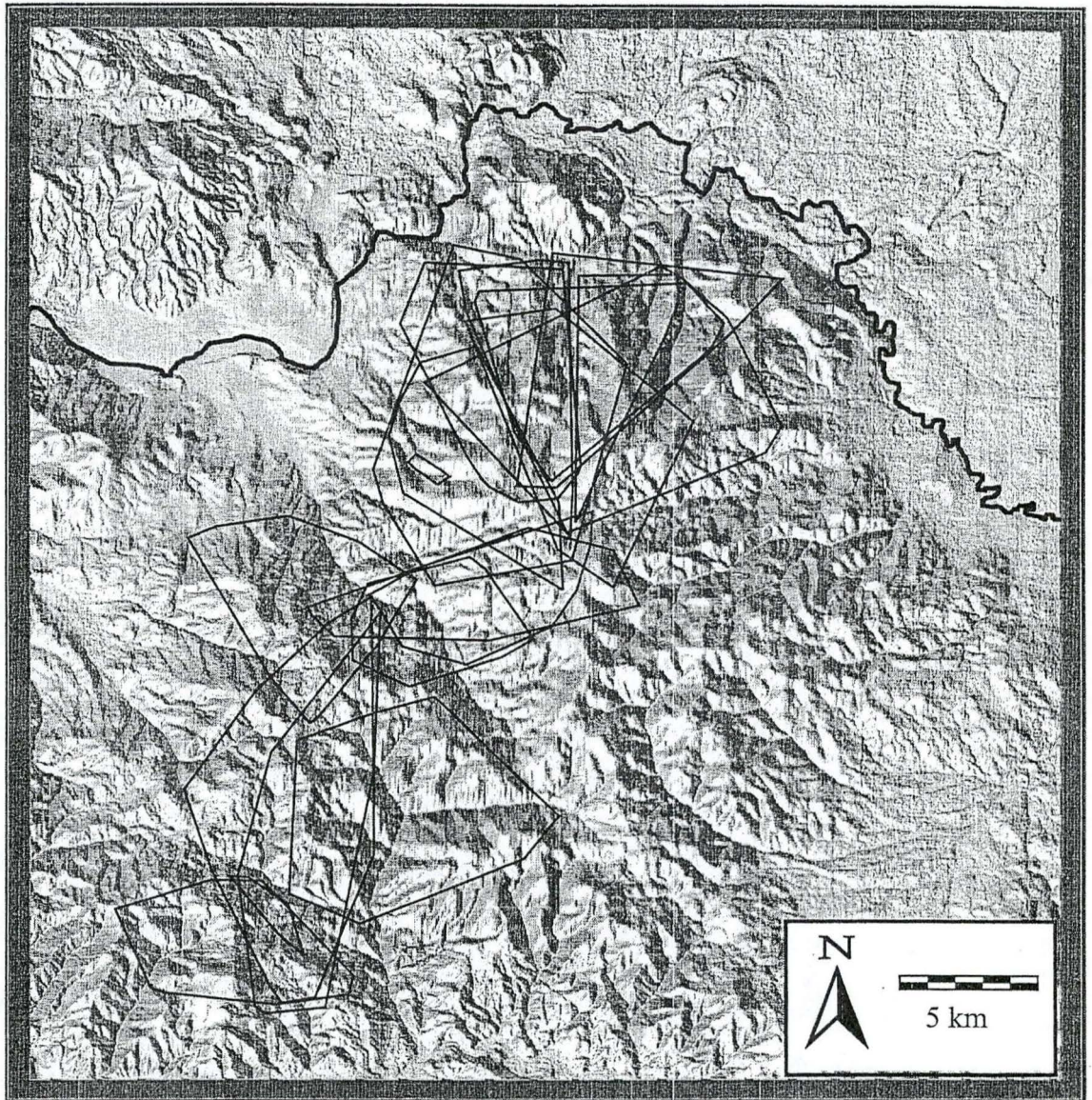


Figure 23. 100% minimum convex polygon home ranges for all moose from the study.

DISCUSSION

Capture and monitoring

Capture - Net gun capture operations were highly successful, with 12 moose caught in December 1997, and 7 more during February 1999. We therefore had a sample of 19 moose (10 females and 9 males) to conduct the study. We captured 5, 6, and 7 moose/day using contracted net gun crews in Hughes 500D helicopters. The mostly forested cover in our study area created difficult conditions for any aerial capture technique and resulted in relatively long search times for moose. We averaged approximately 1 animal per hour during the capture operations and were able to capture most of the animals sighted. Only 2 moose sighted in dense, continuous lodgepole pine could not be driven to an open area for capture. Chase times were limited to 15 minutes and all animals were released in good condition. There were no major injuries, but some animals suffered minor cuts. The handling of animals as large as moose was arduous and well trained crews were necessary to untangle them from nets and hobble the animals. Carpenter (1995 and 1996) reported the net gun technique to be quick, safe, and humane for capturing large numbers of moose. Another advantage of net-gunning is that immobilizing drugs are not needed. Preferred immobilizing drugs for moose are powerful narcotics that are dangerous for humans to handle, and could be consumed by humans that harvest research animals (Franzmann 1997). However net-gunning is expensive and may not be as useful for capturing specific individuals, or catching small groups of animals (Franzmann 1997). We paid an average of \$630 per moose captured for 20 captures in 2 years. We targeted an individual moose only once, a male with a collar that worked intermittently, and captured that animal on our first attempt.

Results from the pilot project in 1996-1997 were not conclusive and added little to the

project, overall. We had only one day for the capture operation. Poor weather and deeper than average snow for December made finding moose difficult, and we only captured 2 moose. The capture related mortality of one of them, made it cost ineffective to monitor the remaining moose the following year. The drug related mortality took place approximately 1 km from the release location, possibly as a result of hypothermia after relapsing to the effect of the drug. Haigh et al. (1977) reported a moose mortality after release, 500 m from the release site, although a different drug was used. The remaining bull was harvested the following fall. These 2 animals were not included in any analyses. No radio-locations were obtained from these animals and with such a small sample, little could be concluded about the use of carfentanil or survival of bull moose during the hunting season.

Monitoring - Telemetry flights were scheduled at approximately bi-weekly intervals for the duration of the study. We considered the bi-weekly interval more than adequate for independence of locations for such a large and mobile animal. All animals were located during almost every flight to minimize location biases. If animals are repeatedly missed in inaccessible locations, location biases result (White and Garrott 1990). No dispersals by individual moose were noted during the study.

Vegetation Plots

One disadvantage to using satellite derived vegetation maps for analyzing wildlife habitat selection is that they do not reveal understory plant species. Moose forage primarily on browse and the presence of shrub communities, even under forest canopy, may play an important role in habitat selection. For this reason, we attempted to obtain additional information on vegetation occurring at a sample of moose locations.

Willow, alder, serviceberry, red osier dogwood and false huckleberry were found at 30-50% of vegetation plots we visited. While examining elk habitat use and food selection, in what we are referring to as the moose/elk study area, Edge et al. (1985) measured occurrence of plant species at elk and random locations. Although frequency of occurrence for all shrub species were not reported, some of the species frequently used by elk were reported. Willow was reported at 24% of random locations, alder at 25%, and serviceberry at 49%. For comparison, we found willow at 51% of moose locations, alder at 48%, and serviceberry at 44%. If random points within the moose/elk study area could be used to represent the entire moose study area, then data suggest that moose were selecting for sites with willow and alder. Frequency of red osier dogwood occurrence was not reported, however, it is likely that it was less common than either willow or alder, suggesting that moose may select for sites containing red osier dogwood as well. Red osier dogwood showed a higher level of browsing than any other shrub species at moose locations.

Many authors have reported the importance of deciduous browse to Shiras moose, indicating an almost complete browse diet during fall and winter (Knowlton 1960, Houston 1968, Stevens 1970). Several of these same authors reported that while willow may have been the most common browse species in Shiras moose diets, red osier dogwood was probably the most preferred browse species and was often heavily over-used on moose ranges (Knowlton 1960, Smith 1962, Stevens 1970, Jenkins et al. 1987).

Habitat Selection by Moose

Moose in our study area selected mesic shrub habitats, gentle slopes, and were found closer to mapped water than randomly expected. Other patterns that emerged included avoidance

of non-forested areas, and the dry aspects and selection for aspen and rocky areas. Although these were the general patterns, there was variations in models which we will discuss individually.

Resource selection functions (RSF's) for moose selection all had low r^2 values, indicating that much variation remains unexplained by variables in the models. Some of this was expected. Moose locations were compared to a sample of random points, rather than points unused by moose. Certainly, some of these random locations represented quality moose habitat, if not actual moose locations. Without knowing where every moose in the population was at all times, unused areas could not be known. The Landsat derived vegetation map had a reported correct classification rate of 62.38%. Classification errors were greatest among similar vegetation types in the initial classification and some of this error would have been corrected when the original 38 vegetation types were combined into the 7 vegetation classes used in these analyses. Still, vegetation classification errors remained. Also, overstory vegetation mapping is a poor predictor of understory vegetation communities, including shrubs, which play an important role in habitat selection by moose.

Yearlong - On a yearlong basis, moose selected for mesic shrub patches, gentle slopes and places near perennial water. Use of shrub dominated habitats by moose is well known from other studies of Shiras moose in Montana (Knowlton 1960, Stevens 1970, Smith 1962, Stone 1971 and others). Although mesic shrubs were a relatively rare habitat type in our study area, moose did select this type when it was available. Moose selection for areas near mapped water was also a reflection of their preference for shrub communities. The riparian shrub communities along most streams in the study area were generally too small to be mapped. They were often

under forest canopy, and therefore were not a part of the mesic shrub type in the GIS. Most streams in the study area, however, supported a community of red osier dogwood which, although not usually present in high enough quantities to make up most of their diet, did seem to be among the most preferred browse species for Shiras moose (Knowlton 1960, Smith 1962, Stevens 1970). Other variables identified by the yearlong moose model could also be explained in terms of the presence of palatable shrubs. Moose avoided non-forested areas such as grasslands and new (<15 year old) clearcuts with little or no shrub cover. These dry upland grasslands and clearcuts in early successional stages supported few of the mesic shrubs preferred by moose. Moose selected for northeast aspects where the cooler, wetter sites favored tall shrub growth. Moose also selected for aspen stands where aspen twigs and bark are eaten as well as other palatable shrub species that were often associated with aspen. The selection of the rock type was not expected, however, this can also be explained in terms of shrub growth. The Elk Creek Burn (1961) which was heavily used by several individual moose did contain rocky areas that were often near moose locations. Also, a female moose spent much of 1 winter near a talus slope in the Wales Creek drainage. Shrubs such as Scouler willow and serviceberry and palatable tree species such as aspen often grow along the margins of talus slopes in the study area.

Winter - The first variable in the winter model, a negative correlation with wet coniferous forest, could simply indicate that moose used lower elevations in winter, where less of this forest type was found. There was a strong positive correlation between elevation and wet coniferous forest, and a negative correlation with dry coniferous forest. As in the yearlong model, other variables in the winter model also suggest preference for a browse diet, including a preference for

the mesic shrub type and aspen types, and a tendency to be near mapped water and its associated riparian shrub community. Moose also avoided non-forest types and were found on more gentle terrain in winter.

All available research on Shiras moose in Montana, in fact on North American moose in general, indicate their almost complete dependence on browse in winter (Peterson 1955, Houston 1968, Knowlton 1960, Stevens 1970, Smith 1962, Stone 1971). Although willow makes up the bulk of moose diets throughout their range, habitat conditions in the Garnet Mountains are probably different than those reported in other moose habitat studies. Extensive willow flats are almost completely absent in the Garnet Mountains, requiring moose to find browse in mesic shrub communities that are still available in winter, and along the narrow riparian areas.

Moose movement to winter range is gradual, and occurs throughout winter (Stevens 1970). Early in winter, December and January, many moose remained at high elevations, even though snow may have been quite deep (> 60 cm). Moose used higher elevation browse habitats, such as the Elk Creek burn and old clearcuts, until the snow pack became more dense and impeded moose movements. It was at this time that moose made more extensive use of browse along streams under forested canopies. Aspen was selected by the moose that had it available to them at the lower elevations, but occurred only in small, isolated stands in the study area.

Spring - Moose selected the cool, wet aspects and areas near mapped water at this time of year. There is little other information on habitat selection by moose in spring. Stevens (1970) reported that moose used greening willows within Douglas fir cover types and also used willow and subalpine fir saplings within spruce-fir forest types. Costain (1989) reported that security was a key element for calving moose in the Yaak drainage of northwest Montana. Langley

(1981) found much variability in calving sites, yet noted that they had more cover than available habitats. During our study, one cow moose made a notable movement during the calving season of 1999. For 3 telemetry flights (22 and 27 May, 11 June) female 04 was located near the summit of Granite Mountain (2,099 m) in deep snow when most of the study area was snow-free or patchy. Prior locations were near a stream bottom below the snow line. On 18 June she was observed with twins in a nearby clearcut, again at a lower elevation.

Summer - The most important summer habitat elements to moose in the Garnets appeared to be the mesic shrub type, northeast aspects, and rocky areas. Once again, these are areas that are associated with shrubs preferred by moose as forage. Houston (1968) reported that in summer, up to 25% of the diet of Shiras moose near Jackson, Wyoming consisted of forbs. Shrubs still comprised most of their summer diet. However, rather than browsing twigs, moose often stripped green leaves from the stems of shrubs. In the Yaak drainage of northwest Montana, Matchett (1985) and Costain (1989) found that moose used forest stands such as select cut spruce (a wet coniferous forest type), and damp timber bottoms. Matchett (1985) also observed that moose alternated between these forested sites and lowland aquatic feeding sites. Moose in the Garnets had no similar aquatic feeding sites available to them.

Fall (rut and hunting season) - Although fall moose models also contained variables associated with palatable shrubs, other variables in the rut and hunting season models were not important at any other season. During the rut (15 September - 20 October) moose avoided areas near both any roads and roads open to motorized vehicles. During the general hunting season for elk and deer (approximately 21 October - 30 November); when human disturbance levels are highest, distance to road was the second most important variable in the model. Moose appeared

to avoid roads in the same way that has been well documented for elk (Marcum 1975, Perry and Overly 1976, Lyon 1979, Lyon et al. 1985, Lyon and Canfield 1991). The result of this displacement on moose, however, is different than that observed for elk. Elk, especially bull elk in a general bulls-only hunting season, may suffer heavy hunting mortality if security habitat is inadequate (Leptich and Zager 1991, Youmans 1991). Moose, on the other hand, would not suffer increased mortality because they are exposed to relatively light hunting pressure. To ensure that moose and elk enter winter in as good condition as possible, quality forage, distant from roads could be important. Moose return to a diet comprised almost entirely of browse in fall (Stevens 1970).

Moose Use of Disturbance Classes

The most consistent result from the analysis of forest disturbance classes was that the majority of radio-collared moose used new clearcuts less than their availability. The lack of shrub growth in newer cutting units probably accounted for this lack of use. Similar findings have been reported from other studies of Shiras moose (Matchett 1985, Costain 1989, Stevens 1970). However, in the Gallatin Valley, Schladweiler (1974) reported that cut-over areas (of unspecified age) accounted for 20% of aerial moose observations in November and December, 19% from May through August, and 10% in September and October. When habitat use by radio-collared moose was reported from the same area, he found that moose used logged areas near their availability in summer, and not at all in winter. An extensive area of intensive logging and scarification between 100 m leave strips in an Alberta white spruce (*Picea glauca*) forest reduced summer and winter use by moose 5 years later (Stelfox 1962). Seventeen years later, after removal of the leave strips in year 12, moose densities were still low in summer, and non-existent

in winter, despite increased forage production in the logged areas (Stelfox et al. 1976). Weaver et al. (unpublished data) found no winter moose use in the same area 34 years later, due to the lack of mature coniferous forest cover nearby.

Old clearcuts (> 15 years old) with conifer regeneration and the Elk Creek burn (37 years old) were used at levels much greater than their availability by 3 individuals, suggesting their importance to some moose. Browse species were abundant in some of these regenerating forests, and dense young saplings provided cover. We observed moose using these sites in summer, fall, and early winter until deep snow caused moose to move to lower elevations in late December or early January. In the Yaak drainage in northwest Montana, Costain (1989) found that uncanopied, logged areas with abundant, high quality forage and good hiding cover were important to moose in all seasons, and they used 12-30 year old stands at mid to low elevations in shallow snow winters. Stevens (1970) found more use of re-vegetated logged areas in winter than at any other time of the year in the Gallatin Valley.

Moose and Elk Spatial Separation

Moose spent more time in areas little used by elk on a yearlong basis, and less time in areas heavily used by elk on a yearlong basis. These differences were significant in winter but consistent throughout the year. Even in summer, when browse used by moose tends to be reduced and when their opportunity to use higher elevation non-winter elk habitat was greatest, moose still made substantial use of the lowest elk use category. Rounds (1982) found the distributions of sympatric moose and elk to be independent of one another in Manitoba. Studies in Montana indicate that the 2 species separate not necessarily due to social intolerance but because of distinctly different habitat preferences. (Stevens 1974, Singer 1979). Jenkins et al.

(1988) found spatial separation of moose and elk during winter in northwest Montana based on different snow depths. Moose preferred areas with > 60 cm, and up to 100 cm of snow, while elk preferred areas with < 60 -80 cm, and strongly avoided deeper snow. Telfer and Kelsall (1984) found that the ecological separation was most pronounced for moose, which foraged in deeper snow than other cervids.

Two years of telemetry data from a large sample of elk, which are herd animals, ensured that we could map elk use within herd boundaries with some accuracy. Moose location densities, because they are a relatively solitary species, cannot be mapped the same way. Areas without moose locations could simply be occupied by moose we did not capture, while areas with many moose points could simply represent several overlapping moose home ranges. Thus, we were only able to test how moose used areas that elk preferred, but not how elk used areas that moose preferred.

Moose and Elk Habitat Selection

Within the moose/elk study area, seasonal models for each species showed distinct differences. The most notable difference was that moose were found near mapped water while elk were found farther from mapped water (Figure 24).

Yearlong - Distance to water was the most important variable in the models for yearlong moose and elk distributions. The proximity of moose locations to mapped water, as in the moose models for the entire study area, is probably related to the presence of riparian shrub communities. The fact that elk were found further from mapped streams is not as easy to explain, since several studies have documented their preference for water as well, especially in summer (Jeffrey 1963, Nelson and Burnell 1975, Mackie 1970, Lyon 1973). The difference

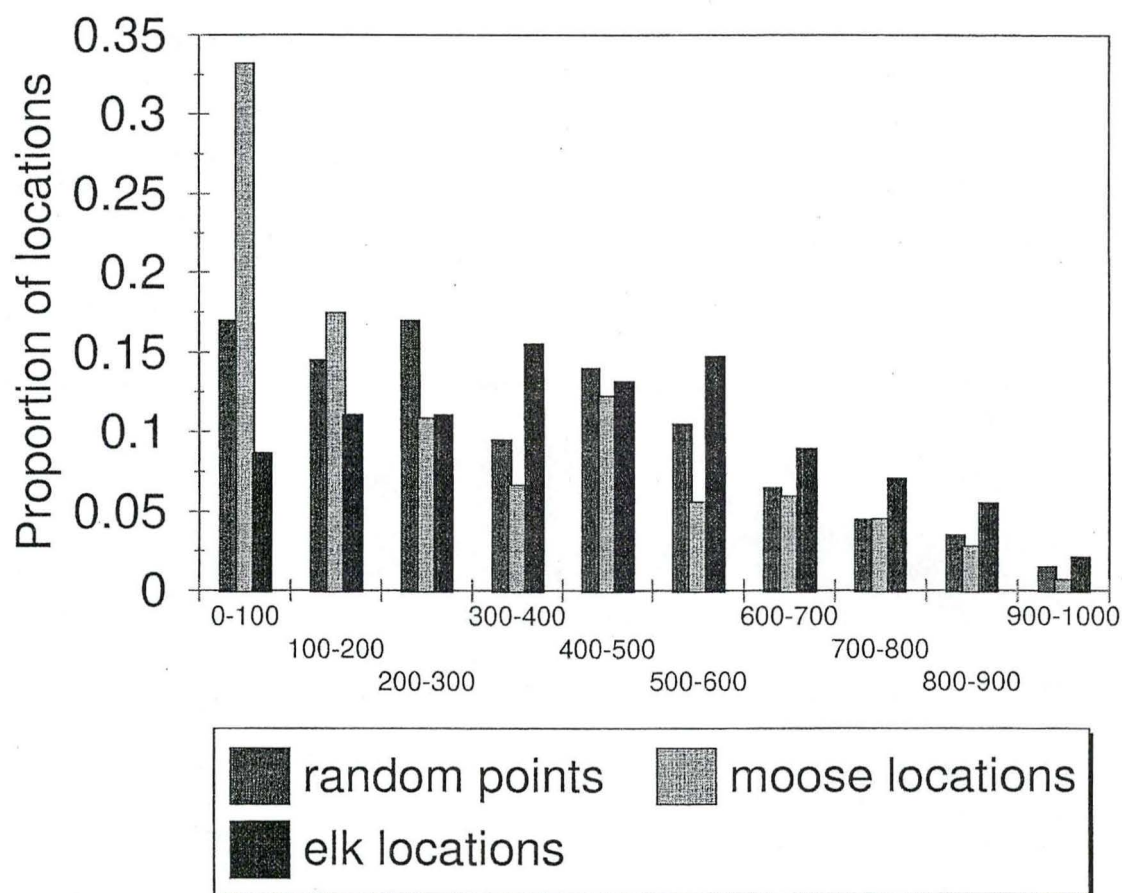


Figure 24. Distance to mapped water (m) of random points and moose and elk locations.

could relate to the nature of the hydrography layer from USGS 7.5 minute topographic maps, used in these analyses. USGS hydrography in the study area consisted of perennial and intermittent streams. However, there appears to be a tendency for the mapping to be incomplete, especially for smaller creeks, streams, and springs which are the areas most preferred by elk (Marcum 1975). Mapped water included the larger streams in the study area, and they were most likely to host riparian shrub communities attractive to moose. Smaller water sources, such as headwaters, 1st order streams, and springs were less likely to be mapped. These smaller water sources are adequate to provide elk with drinking water, wallows, herbaceous forage, and cool resting sites in summer. Elk avoided the confining topography of larger streams, while moose used these area intensively, especially in winter. This was especially evident in the small canyon formed by much of Chamberlain Creek.

Winter - The winter model for moose within the moose/elk study area was very similar to that developed for the entire study area. Selection for areas near mapped water and mesic shrub types was most important, reflecting the reported reliance of moose on browse at this time of year. Moose avoided wet coniferous forest, again, reflecting their use of lower elevations where this type is scarce. Few winter elk locations were obtained so no winter model for elk could be created for comparison with moose in this study. In areas where grasses were available, elk preferred them, especially on south slopes where snow depths remained shallow (Stevens 1974, Jenkins et al. 1987). During the winter of 1996-1997 the study area received record snowfalls, producing a snowpack in excess of 90 cm even at low elevations, where the normal snowpack is often less than 30 cm. During this winter we observed heavy elk use of low elevation, mature Douglas fir forest stands with high canopy closure. Stevens (1974) reported that interspecific

competition between moose and elk occurs only when forage resources have been depleted or weather conditions are severe. In the North Fork of the Flathead River valley in northwest Montana, Jenkins et al. (1987) found that deep snow winters increased the overlap of moose and elk diets. Generally, moose preferred hydric shrub and lowland spruce communities, and elk preferred lodgepole pine savannahs (Jenkins et al. 1988). During a severe winter, moose used more lodgepole pine, while elk used more mature forest (Jenkins et al. 1988). In Banff National Park, where elk occurred at high densities Hurd (1999) suggested that willow, an important food source for moose, was limited by elk browsing, and suggested exploitive competition between elk and moose. The large asymmetries in distribution, abundance, diet breadth, diet overlap, and browse utilization provided conditions for elk to dominate competitive interactions (Hurd 1999). The hunted elk population in our study area, occurred at much lower densities, so there was probably little forage competition between elk and moose.

Spring - In spring, moose were found near open roads while elk locations tended to be distant from the mapped water and absent from wet coniferous forest. Habitat use by both species was variable during the study. Models generally reflected a preference for lower elevations. Behavior of female elk at this time of year was distinct. Rather than occurring in groups with other female elk, cows isolated themselves for 1-2 weeks before joining large herds of other females and newborn calves later in June. No strong patterns of habitat selection by female moose during parturition were noted, with the exception of the movement to high elevation by a female that had twins, as noted previously.

Summer - Summer represents the greatest opportunity for moose and elk to use the same space, although our models do not show strong selection for any variables that would indicate

potential competition. In other studies of Shiras moose Houston (1968) and Schladweiler (1974) reported the greatest use of forbs in summer. Forbs and grasses, make up most of the diet of elk in summer. In our spatial analyses, moose used areas of moderate elk densities greater than the availability of such areas, although these differences were not significant ($P = 0.10$). McMillan (1953) found Yellowstone elk to be associated with moose greater than expected by chance on summer moose foraging areas, and recognized the potential for high elk densities to damage willow forage resources critical to moose.

Fall - Both moose and elk were positively correlated with wet coniferous forests such as Engelmann spruce, subalpine fir, and lodgepole pine in the fall. Both species could be using stands of timber as security cover from increased disturbance by humans during the hunting season. This behavior is well documented for elk (Marcum 1975, Irwin and Peek 1983, Canfield 1988). Although the majority of hunting pressure was not directed at moose, they probably sought hiding cover to minimize the increased human disturbance.

Use of Security Attributes by Moose and Elk

Landscape features thought to benefit bull elk survival during the hunting season have become important considerations to land managers. Elk have been shown to avoid roads, especially those open to motorized vehicles (Marcum 1975, Perry and Overly 1976, Lyon 1979, Lyon et al. 1985, Lyon and Canfield 1991), and to use large blocks of forest cover (Marcum 1975, Irwin and Peek 1983, Canfield 1988). How moose respond to these landscape features is not well known.

Both moose and elk avoided of roads. However, this displacement for moose tended to be only during the hunting season, while elk displayed this behavior yearlong. Moose use of

areas near roads outside of the hunting season could have been a reflection of roads commonly being located in valley bottoms, near creeks that support riparian shrub communities. Although the variable in this analysis was distance to nearest road of any type, few roads that were open to motorized vehicles yearlong existed within the moose/elk study area. Therefore, this response is largely to roads closed year-round to motorized vehicles. Even though these roads were closed to motorized vehicles, they received light administrative use throughout the year, and were heavily used by hunters on foot, horse or bicycle during the hunting season (Lyon and Burcham 1998). Hunting season data suggested that the displacement from these roads may be largely to areas at least 200-300 m from roads for both moose and elk. During the non-hunting season, data suggested that elk may only be displaced to areas 100-200 m from roads.

Data on distance of moose and elk locations to open roads were more difficult to interpret. Proportions of elk locations increased, in both hunting and non-hunting seasons, as distance from open roads increased, to 4,000 m. Moose distances from open roads showed no pattern, although moose made slightly greater use of areas 1,000-2,000 m from open roads during the hunting season, and less use of areas 2,000-3,000 m from open roads. Fewer than 15% of both hunting and non-hunting elk locations were within 1,000 m of open roads, while 20-25% of moose locations were within 1,000 m of open roads, suggesting that moose may be less affected by open roads than elk.

Hillis et al. (1991) suggested that blocks of hiding cover for elk in the hunting season should exceed 100 ha (250 acres). We examined the proportion of forested cover (>39% canopy cover) within 100 ha (250 acre), 200 ha (494 acre), and 400 ha (988 acre) areas centered on moose, elk, and random locations. Generally, moose used these forested areas less than expected

and this became more significant as scale increased. Although these large forested areas may not represent ideal conditions for moose in the Garnets, these areas still accounted for a substantial portion of moose locations. The narrow riparian shrub communities and residual shrub component to the understory, are probably important to moose in these areas.

Elk showed a preference for large, mostly forested areas. Although this difference was not significant when open forest types (10-39% canopy cover) were left out of the analysis, it was significant at the largest scale when all forest types were considered. These results imply that large forested areas (400 ha) may be more preferred by elk than smaller ones (100-200 ha).

Population Parameters

Observability - The observability of moose during telemetry flights varied considerably throughout the year, and could have a large influence on timing and reliability of moose counts. Radio-collared moose were most visible during the months of December and January and most difficult to observe from April through September. The high observability of moose in December and January coincided with the lowest estimated tree canopy cover at moose locations and the least visible period coincided with the highest tree canopy coverage at moose locations. Average snow depth at moose locations probably also plays a role in visibility of moose, but observability did decline during February and March when average snow depths at locations remained high. Deeper, and perhaps more dense snow packs later in winter caused moose to seek forest stands with higher canopy closures. The presence of snow cover may be more important than snow depth. Only 12% of moose locations without snow on the ground ($n = 404$) resulted in a visual location, while 62 % of locations with snow on the ground ($n = 348$) were visually confirmed. The optimal aerial viewing conditions (94% visual locations) during our study took place during

December when canopy coverage at locations averaged 34%, and snow coverage was complete with an average depth of approximately 30 cm at moose locations.

Moose survey - Previous efforts to count moose in the Garnet Range produced variable results, with from 0 to 20 moose counted on 7 different efforts from 1978 through 1996. Our count of 44 moose (19 females, 16 males, 9 calves) using a modified Gasaway et al. (1986) survey, represented the most intensive effort to count moose in the Garnet Range to date. Conditions for the count were ideal with fresh snow covering the entire study area and good weather for most of the count. However, it still provides only a rough population estimate. Funding constraints did not allow this count to be replicated. At least 3 counts would be needed to permit calculation of confidence limits around the population estimate of 64 moose. Also, this count does not represent the population for the entire Garnet Range, but only the animals within the count area. Substantial moose habitat existed outside the count area, particularly in the southeastern portion of the Garnets, including Wales, Yourname, Murray and Douglas creeks, and the numerous drainages west of the study area. We recorded a ratio of 47 calves/100 females, with no twins observed. This ratio is towards the lower end, but still within the range, of ratios reported for other Shiras moose populations in Montana, Idaho, and Wyoming (Pierce 1983, Stevens 1970, Knowlton 1960, Peek 1962, Ritchie 1978, Schladweiler 1974, Houston 1968). The bull:cow ratio we observed of 84:100 is high when compared to the range of other hunted moose populations in Montana, Idaho, and Wyoming, which ranged from 41 to 81 (Houston 1968, Pierce 1983, Schladweiler 1974, Ritchie 1978, Matchett 1985, Costain 1989). The present allocation of 6 bull-only permits for the Garnet Range does not seem excessive.

Calf production - The single moose calf observed with our radio-collared sample of cows

in summer 1998 would be reason for alarm if taken alone. The observed calf:cow ratio of 17:100 is lower than observed in most North American moose populations (Schwartz 1997). A potential reason for the low calf count in 1998, was stress from the severe winter of 1996-1997, which could have still have affected the ability of cows to carry a calf full-term. Few calves were observed during the entire 1998 field season or during the second moose capture in February 1999, suggesting the entire population could have been affected. The pregnancy rate we measured from blood serum collected during our 1997 capture, 5 of 7 cows pregnant or 71%, was also lower than reported for other moose populations in North America, which ranged from 78 to 100% (Schwartz 1997). Other research priorities prevented all radio-collared females from being observed early in summer, so some calf mortality could have taken place before calves could be observed.

Calf production during 1999 showed much improvement. Seven calves were observed with 5 of the 9 radio-collared females (78 calves:100 cows). This included 2 females with twins for a twinning rate = 40%. This compares favorably with other reported twinning rates for moose in Montana, ranging from 16-50% (Schladweiler 1974, Matchett 1985, Costain 1989), and even from other populations in North America (Houston 1968, Schwartz 1997). Twinning rates in adult moose are likely correlated with habitat quality and the relationship of each moose population to carrying capacity of their habitats (Franzmann and Schwartz 1985, Gasaway et al. 1992). Females were observed earlier in 1999 than 1998, although, it is still possible that some calves died before they could be counted.

Moose on poor range may not reproduce in consecutive years (Albright and Keith 1987). We did not have a good opportunity to test this, since reproduction was so low during the first

year of the study. The only female known to produce a calf in 1998, did not have one in 1999.

Mortality - Mortality of radio-collared moose during the study was low. Hunters accounted for only 1 mortality of 9 radio-collared bull moose during 2 hunting seasons. Sample sizes of radio-collared bull moose for the two hunting seasons were too low to place much confidence in hunting mortality estimates, but hunting mortality for the 2 years was only 11%.

Not enough evidence was available to determine the cause of death for the female that died in spring 1998. The mortality occurred near calving season and the female had tested positive for pregnancy when captured the previous December. Mortalities resulting from fights between male moose, as we observed, are well documented but are probably not significant factors in moose population dynamics (Child 1997). Langley (1993) documented predation on adult Shiras moose by both wolves and grizzly bears near Glacier National Park. However, both predators are largely absent from the Garnet Mountains. Some predation on moose calves by black bears is likely. Black bears can kill up to 50% of calves in a moose population (Ballard and Van Ballenberghe 1997).

MANAGEMENT RECOMMENDATIONS

1. When dealing with a relatively low density moose population, such as occurs in the Garnet Range, there appears to be minimal conflict in providing security habitat for elk during the hunting season, and yearlong habitat for moose. Moose seem to prefer landscapes that are 25-75% forested and use areas that are more than 75% forested less than expected by availability. Large areas that are mostly forested, however, do receive substantial use by moose.

Approximately 30% of moose locations were found in such areas, even when looking at a relatively large scale (400 ha). Security areas for elk could be designed to minimize conflict with moose habitat needs by providing security areas on ridge tops and drainage heads, rather than near valley bottoms and intermittent and perennial streams that host riparian shrub communities. Over 30% of moose locations were within 100 m of mapped creeks and streams, while less than 10% of elk locations were in these areas. Upper slopes, ridges and drainage heads, are used less by moose than by elk. Large forested areas that contained drainages, even if they are narrow and under forest canopy, would receive more use by moose.

Some forested areas within the study area seemed more attractive to moose than others. The lodgepole pine forests within the granitic soils of Kennedy and North Fork of Elk Creeks, were well used by moose. Residual shrubs from previous wild fires and shrubs associated with rock outcrops, could have provided forage in these areas.

Our results showed that the larger forested areas (400 ha), were preferred by elk and would provide the greatest benefit to elk during the hunting season. This provides managers with the opportunity to balance the size of forested stands to meet the needs of both moose and elk.

2. Road management is important to moose during hunting season, and to elk year-round. Moose may be displaced up to 300 m from roads during the hunting season. Constructing roads at least 300 m from preferred moose habitats could increase their availability to moose. Keeping roads away from preferred moose habitats could also minimize illegal moose kills.

3. The relatively narrow riparian shrub communities found throughout the Garnets, especially those hosting red ozier dogwood and willow, provide the most stable habitat for moose over time. Maintenance of riparian areas and riparian shrub communities, even those that occur under forest canopies, provide a network of habitat throughout the Garnets. The riparian shrub communities under forest canopies can be especially important in periods of deep snow. Considering the results of this study and ecology of these riparian shrub communities, overstory removal or other vegetation manipulations in riparian zones in the Garnets would not constitute habitat improvements for moose.

4. Clearcuts and areas that have received stand replacement fires, that are from 15 to 40 years old with dense regeneration and deciduous shrub growth, provide highly desirable moose habitat. Willow, alder, serviceberry, red ozier dogwood, and false huckleberry were well represented at moose locations, and represent key habitat components. However, not all cutting units provide ideal moose habitat after 15 years. Cutting units in the Garnets that provided the best moose habitat in later seral stages tended to be at higher elevations, and on northern aspects. These areas represent the best opportunity to improve moose habitat in the Garnet Range, however, a rotation of these types is important. Younger cuts and burns (< 15 years old) were

avoided by moose, so long-term planning to recruit older seral stages is necessary.

Again, some sites proved more productive than others. The Elk Creek burn of 1961 is still providing preferred moose habitat almost 40 years later. This burn took place on granitic soils with a high water table and the shrubs preferred by moose responded very well. Pre-commercial thinnings of forest regeneration, in the mid 1970's, also could have also prolonged the attractiveness of the Elk Creek burn to moose. Although this habitat remains important for moose, succession towards mature coniferous forest will diminish its exceptional value as moose habitat. Prescribed burning and other appropriate treatments to set back succession in the Elk Creek burn would be highly cost effective where positive vegetation and moose responses are already known from past experience. Other nearby sites such as the North Fork of Elk Creek, Kennedy Creek, and Wales Creek have similar characteristics, and are good candidates for habitat projects that could benefit moose. Conversely, the removal of forest canopy on sites without the high potential for shrub production, would not be expected to benefit moose.

5. Moose counts should be conducted in December or January. December has the advantage of the very highest moose observability, however, moose were normally dispersed over their ranges at this time and still occurred at high elevations. January has the advantage of high observability, and the possibility that moose will be concentrated at lower and mid elevations. As snow depth increases and the snow pack becomes more dense, moose seek more densely forested areas, decreasing their observability. We observed bull moose without antlers by late November, and regularly by mid-December. Therefore, presence of antlers do not represent a reliable way to determine sex of moose during counts at this time.

6. The current harvest of 6 bull moose per year from the Garnet Range (moose Hunting District 292) appears sustainable. There appears to be a diverse age structure in the male segment of the population, hunting mortality of radio-collared bull moose was low, and hunter success is constant. If most of the moose harvest from HD 292 comes from this study area (namely the Elk Creek and Bear Gulch drainages), then an increase in harvest may not be justified based on the population estimate for this area obtained from a helicopter survey. Substantial portions of the Garnets (HD 292) were not surveyed and little is known of moose numbers or moose hunting pressure outside of the study area boundaries: including Wales, Yourname McElwain, Murray, Douglas, Rattler, and Mulkey drainages to the east, and all of the area west of Dry Gulch and upper Union Creek.

LITERATURE CITED

- Albright, C.A. and L. B. Keith. 1987. Population dynamics of moose, *Alces alces*, on south coast barrens of Newfoundland. *Can. Field-Nat.* 101:373-387.
- Ballard, W.B. and V. Van Ballenberghe. 1997. Predator/prey relationships. *In* Ecology and management of North American moose. Franzmann, A.W. and C.C. Schwartz, ed. Smithsonian Institution Press, Washington. 733 pp.
- Burcham, M., C.L. Marcum, L.J. Lyon, K.T. Weber, W.D. Edge. 1998. Final report: Chamberlain Creek elk studies, 1977-1983 and 1993-1996. University of Mont., Missoula. 260 pp.
- Byers, C.R., R.K. Steinhorst, and P.R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manage.* 48(3):1050-1053.
- Canfield, J.E. 1988. Impact mitigation and monitoring of the BPA 500-kV Garrison-Taft transmission line - effects on elk security and hunter opportunity. Final project report. Mont. Dept. Fish, Wildl., Parks. Helena 162 pp.
- Carpenter, L.H. 1996. Helicopter moose capture opens new doors. *The Moose Call*, 3:3.
- Carpenter, L.H. and J.I. Innes. 1995. Helicopter netgunning: a successful moose capture technique. *Alces* 31:181-184.
- Child, K.N. 1997. Incidental mortality. *In* Ecology and management of North American moose. Franzmann, A.W. and C.C. Schwartz, ed. Smithsonian Institution Press, Washington. 733 pp.
- Clover, M. R. 1954. A portable deer trap and catch net. *Calif. Fish and Game* 40:367-373.
- Costain, B. 1989. Habitat use patterns and population trends among Shiras moose in a heavily logged region of northwest Montana. M.S. Thesis. Univ. of Montana, Missoula. 258 pp.
- Crichton, V.F.J. 1997. Hunting. *In* Ecology and management of North American moose. Franzmann, A.W. and C.C. Schwartz, ed. Smithsonian Institution Press, Washington. 733 pp.
- Edge, W.D. 1985. Habitat use and food habits of elk in western Montana. PhD Thesis. University of Montana, Missoula. 75pp.
- Edge, W.D., C.L. Marcum, and S.L. Olson. 1985. Effects of logging activities on home range fidelity of elk. *J. Wildl. Manage.* 49:741-744.

- ESRI. 1994. ARC/INFO version 7.0. Environmental Systems Research Institute, Inc. Redlands, California.
- Franzmann, A.W. and C.C. Schwartz. 1985. Moose twinning rates: a possible population condition assessment. *J. Wildl. Manage.* 49:394-396.
- Franzmann, A.W. 1997. Restraint, translocation, and husbandry. *In* Ecology and management of North American moose. Franzmann, A.W. and C.C. Schwartz, ed. Smithsonian Institution Press, Washington. 733 pp.
- Gasaway, W.C., S.D. DuBois, D.J. Preston, and D.J. Reed. 1986. Estimating moose population parameters from aerial surveys. *Biol. Pap.* 22. University of Alaska-Fairbanks. 108 pp.
- Gasaway, W.C., R.D. Boertje, D.V. Grandgard, K.G. Kellyhouse, R.O. Stephenson, and D.G. Larson. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. *Wildl. Monogr.* 120. 59 pp.
- Haigh, J.C., R.R. Stewart, G. Wobeser, and P.S. MacWilliams. 1977. Capture myopathy in a moose. *JAVMA*, 171(9):924-926.
- Hammond, H. 1983. Garnet: Montana's last gold camp. Acme Press, Missoula. 52 pp.
- Hillis, J.M., M.J. Thompson, J.E. Canfield, L.J. Lyon, C.L. Marcum, P.M. Dolan, D.W. McCleerey. 1991. Defining elk security: the Hillis Paradigm. Pages 38-43. *in* A.J. Christensen, L.J. Lyon, and T.N. Lonner, comps., *Proc. Elk Vulnerability - A Symp.* Montana State Univ., Bozeman, 330 pp.
- Houston, D.B. 1968. The Shiras moose in Jackson Hole, Wyoming. *Grand Teton Nat. Hist. Assoc. Tech. Bull.* 1. 110 pp.
- Hurd, T.E. 1999. Factors limiting moose numbers and their interactions with elk and wolves in the central Rocky Mountains, Canada. M.S. Thesis, Univ. of British Columbia, Vancouver. 82 pp.
- Irwin, L.L. and J. M. Peek. 1979. Relationship between road closures and elk behavior in northern Idaho. *In* North American elk: ecology, behavior and management, ed M.S. Boyce and L.D. Hayden-Wing. pp 199-204. Laramie: Univ of Wyoming. 294 pp.
- Jeffrey, D.E. 1963, Factors influencing elk and cattle distribution on the Willow Creek summer range, Utah. M.S. Thesis. Utah State Univ., Logan. 46 pp.
- Jenkins, K.J. and R.G. Wright. 1987. Dietary niche relationships among cervids relative to winter snowpack in northwestern Montana. *Can. J. Zool.* 65:1397-1401

- Jenkins, K.J. and R.G. Wright. 1988. Resource partitioning and competition among cervids in the northern Rocky Mountains. *J. Appl. Ecol.* 25:11-24.
- Knowlton, F.F. 1960. Food habits, movements, and populations of moose in the Gravelly Mountains, Montana. *J. Wildl. Manage.* 24:162-170.
- Langley, M.A. 1993. Habitat selection, mortality, and population monitoring of Shiras moose in the North Fork of the Flathead River Valley, Montana. M.S. Thesis. Univ. of Mont., Missoula. 162 pp.
- Leckenby, D.A. 1984. Elk use and availability of cover and forage habitat components in the Blue Mountains of northeast Oregon, 1976-1982. Wildlife Research Report Number 14. Oregon Dept. Fish and Wildl., Portland. 40 pp.
- Leptich, D.J. and P. Zager. 1991. Road access management effects on elk mortality and population dynamics. Pages 126-131. *In* A.J. Christensen, L.J. Lyon, and T.N. Lonner, comps., *Proc. Elk Vulnerability - A Symp.* Montana State Univ., Bozeman, 330 pp.
- Lincoln, F.C. 1930. Calculating waterfowl abundance on the basis of band returns. U.S. Dept. Agric. Circ. 118. 4 pp.
- Lyon, L.J. 1973. Elk use of Burdette Creek. Pages 101-106. *In* Western States Elk Workshop Proc., Bozeman, Mont., Feb 20-21, 1973.
- Lyon, L.J. 1979. Habitat effectiveness for elk as influenced by roads and cover. *J. For.* 77:658-660.
- Lyon L.J. and M. Burcham. 1998. Tracking elk hunters with the global positioning system. Res. Pap. RMRS-RP-3, UT: U.S. Department of Agriculture, Forest Service Rocky Mountain Research Station. 6pp.
- Lyon, L.J., T.N. Lonner, J.P. Weigand, C.L. Marcum, W.D. Edge, J.D. Jones, D.W. McCleerey, and L.L. Hicks. 1985. Coordinating elk and timber management. Final report, Mont. coop. elk-logging study. Mont. Dept. Fish, Wild., Parks, Bozeman. 53 pp.
- Lyon, L.J. and J.E. Canfield. 1991. Habitat selection by Rocky Mountain elk under hunting season stress. Pages 99-105. *in* A.J. Christensen, L.J. Lyon, and T.N. Lonner, comps., *Proc. Elk Vulnerability - A Symp.* Montana State Univ., Bozeman, 330 pp.
- Mackie, R.J. 1970. Range ecology and relations of mule deer, elk, and cattle in the Missouri River Breaks, Montana. Wildl. Monogr. No. 20. Washington D.C.: The Wildlife Society. 79 pp.

- Manley, B.F.J., L.L. McDonald, D.L. Thomas. 1993. Resource selection by animals: statistical analysis and design for field studies. Chapman and Hall, London, England. 177 pp.
- Marcum, C.L. 1975. Summer-fall habitat selection and use by a western Montana elk herd. PhD Thesis, Univ. of Montana, Missoula. 188 pp.
- Matchett, M.R. 1985. Moose-habitat relationships in the Yaak River drainage, northwestern Montana. M.S. Thesis, Univ. of Montana, Missoula. 229 pp.
- McMillan, J.F. 1953. Measures of association between moose and elk on feeding grounds. J. Wildl. Manage. 17:162-166.
- Nelson, J.R. and D.G. Burnell. 1975. Elk-cattle competition in central Washington. In Range multiple use management. Moscow: Univ. of Idaho. 172 pp.
- Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.
- Oosenbrug, S.M., and S.H. Ferguson. 1992. Moose mark-recapture survey in Newfoundland. Alces 28:21-29.
- Peek, J.M. 1962. Studies of moose in the Gravelly and Snowcrest Mountains, Montana. J. Wildl. Manage. 26(4):360-365.
- Perry, C. and R. Overly. 1976. Impacts of roads on big game distributions in portions of the Blue Mountains of Washington. Pages 62-68. In Proc elk-logging-roads symp. ed. S.R. Hieb. Univ. Idaho, Moscow. 142 pp.
- Peterson, R.L. 1955. North American Moose. University of Toronto Press, Ontario. 280 pp.
- Pierce, D.W. 1983. Food habits, movements, habitat use, and populations of moose in south central Idaho, and relationships to forest management. M.S. Thesis, Univ. of Idaho, Moscow. 205 pp.
- Reeves, H.M. and R.E. McCabe. 1997. Of moose and man. In Ecology and management of North American moose. Franzmann, A.W. and C.C. Schwartz, ed. Smithsonian Institution Press, Washington. 733 pp.
- Ritchie, B.W. 1978. Ecology of moose in Fremont County. Idaho Dept Fish and Game, Boise. Wildl. Bull. 7. 33 pp.
- Rounds, R.C. 1982. Spatial relationships of sympatric populations of wapiti and moose (Cervidae) on winter range in Manitoba. J. of Biogeog. 9:121-133.

- Schladweiler, P. 1974. Moose ecology in southwestern Montana. Job Final Rep. Res. Proj., Montana Department of Fish, Wildl., and Parks. Helena. 100 pp.
- Schwartz, C.C. 1997. Reproduction, natality, and growth. *In* Ecology and management of North American moose. Franzmann, A.W. and C.C. Schwartz, ed. Smithsonian Institution Press, Washington. 733 pp.
- Singer, F.J. 1979. Habitat partitioning and wildfire relationships of cervids in Glacier National Park, Montana. *J. Wildl. Manage.* 43:437-444.
- Smith, N.S. 1962. The fall and winter ecology of the Shiras moose in the Rock Creek drainage, Granite County, Montana. M.S. Thesis, Montana State Univ., Missoula. 52 pp.
- SPSS Inc. 1999. SPSS Base 10.0 user's guide. Chicago, Illinois. 537 pp.
- Stelfox, J.G. 1962. Effects on big game of harvesting coniferous forests in western Alberta. *Forest. Chron.* 38:94-107.
- Stelfox, J.G. G.M. Lynch, and J.R. McGillis. 1976. Effects of clearcut logging on wild ungulates in the central Alberta foothills. *Forest. Chron.* 53:65-70.
- Stevens, D.R. 1970. Winter ecology of moose in the Gallatin Mountains, Montana. *J. Wildl. Manage.* 34(1):37-46.
- Stevens, D.R. 1974. Rocky mountain elk - Shiras moose range relationships. *Naturaliste Can.* 101:505-516.
- Stone, J.L. 1971. Winter movements and distribution of moose in the upper Rock Creek drainage, Granite County, Montana. M.S. Thesis, Univ. of Montana, Missoula. 80 pp.
- Telfer, E.S. and J.P. Kelsall. 1984. Adaptation of some large North American mammals for survival in snow. *Ecology.* 65:1828-1834.
- Thomas, J.W., D.A. Leckenby, A. Donavin, M. Henjum, R.J. Pedersen, L.D. Bryant 1988. Habitat effectiveness index for elk on Blue Mountain winter ranges. Gen. Tech. Rep. PNW-GTR-218. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 28 pp.
- Thompson, M. J., R. E. Henderson, T. O. Lemke, and B. A. Sterling. 1989. Evaluation of a collapsible Clover trap for elk. *Wildl. Soc. Bull.* 17:287-290.
- Weaver, J.L., W. Hughson, C. Arvidson, P.C. Paquet. Unpublished data. Ungulate winter utilization of coniferous forests in west-central Alberta 34 years after logging.

White, G.C. and R.A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego. 383 pp.

Youmans, C.C. 1991. Analysis in long-term trends in elk vulnerability on the Bitterroot National Forest in relation to selected predictor variables. Pages 159-167. in A.J. Christensen, L.J. Lyon, and T.N. Lonner, comps., Proc. Elk Vulnerability - A Symp. Montana State Univ., Bozeman, 330 pp.